THE

PRINCIPLES AND PRACTICE

OF

PERIMETRY

BY

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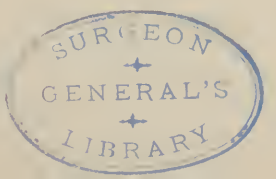

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THESE PAGES

ARE AFFECTIONATELY DEDICATED

TO

MY WIFE

PREFACE TO THE SECOND EDITION.

The cordial reception accorded by the profession to the first edition of this little text-book, the increasing interest in the refinements of perimetry, and the necessity of bringing the subject-matter up to date, are the reasons for offering a second edition, largely rewritten, rearranged, and somewhat enlarged. In the main, the general plan and policies of the first edition have been followed. It seemed to the author, however, that the anatomy and physiology of the visual pathway should be grasped first by the student in order to thoroughly appreciate the necessity for the refinement in technic which has been evolved during the last decade, and to understand the reasons for the changes observed in disease of the various parts of the visual pathway.

Part II, dealing with Physiological Principles and Normal Visual Fields, follows in natural order. In this part, only necessary changes have been made.

Part III, on Methods, Technic, Instruments and Charts, has been rewritten so as to include the most recent ideas of the many who have given time and thought to the subject. The pages on technic should command the careful attention of the student in ophthalmology who hopes to find in field studies the real help which he needs in diagnosis.

In the rewriting of Part V, on Special Pathology of Fields, an effort has been made to differentiate between papillitis and papilledema. Much stress is laid on the minute changes in glaucoma, sinus disease, and especially the changes found in disease of the visual pathway within the brain. Progress in these several conditions has been most noteworthy.

New colored plates and many new and original drawings have been added to illustrate the text and to help the reader to a better visualization of the principles.

The author hopes that these changes may meet with the approval of those who have found the former edition of value to them, and that in its new form, other students in ophthalmology may find its pages helpful in their studies, and a source of inspiration to contribute their share in perfecting this important phase of Ophthalmic Diagnosis.

L. C. P.

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PART I.

ANATOMY AND PHYSIOLOGY OF THE VISUAL PATHWAY.

ANATOMY.

BEFORE taking up the study of normal and pathological fields, it is necessary to briefly review the anatomy and physiology of vision.

Plate I is a diagrammatic sketch of the anatomical visual apparatus in man. The optic nerve enters the posterior pole of the eye 15 degrees to the inner side and a little above the point of central vision or macula. In the disc there are no end-organs for light perception, but immediately beyond the disc's edge the various layers of the retina (the continuation of the optic nerve) are spread out over the interior of the eyeball. To the nasal side, above and below, the nerve fibers spread out in a radial manner; to the temporal side, however, the fibers traverse a greater area to reach the periphery, because they bend around the macular region which is supplied by direct nerve fibers from the papillo-macular bundle of the optic nerve. The longer route of the temporal fibers has a bearing upon the early shrinkage of the nasal field in certain pathological conditions. The retina is rather firmly attached at the point of entrance of the optic nerve and at the ora serrata. Between these points of fixation, it is very loosely connected with the underlying choroid.

It is well to bear in mind this close attachment at the optic disc, because it will explain in a measure certain types of ring scotomata, as for instance, after commotio retinæ, as suggested by Lohmann.

Rods and Cones.—The rods and cones, or perceptive end-organs, have a peculiar distribution. In the fovea, according to Salzmann,[1] only cones are in evidence; beyond the fovea, in the macular region, rods appear; and receding from the macula toward

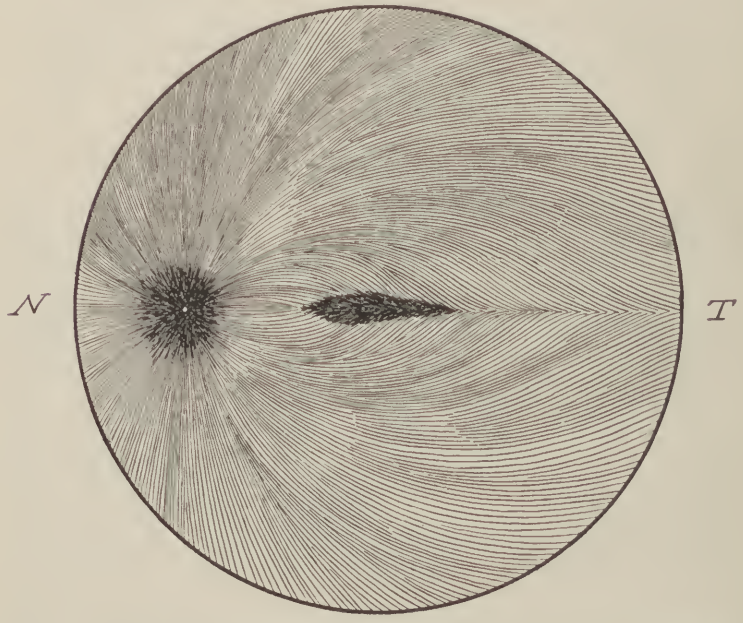
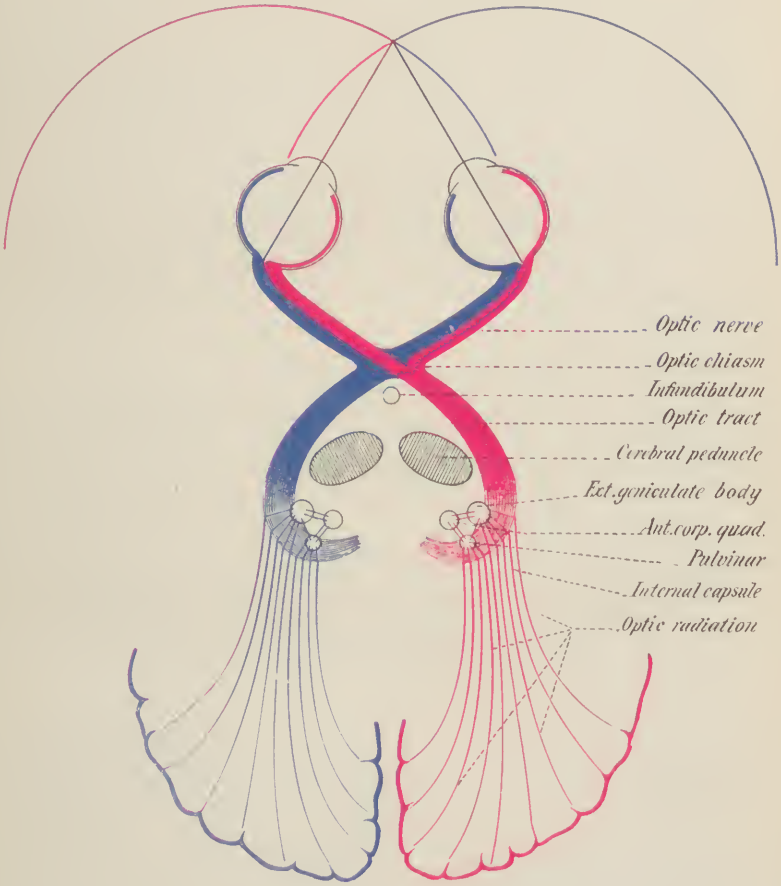


Fig. 1.—Diagram illustrating distribution of the retinal nerve filaments.

the periphery, rods become relatively more numerous and the cones fewer in number, until the extreme periphery is reached, when cones are again in evidence in increasing numbers. In the macular region, each cone has a direct and individual communication with the primary optic centers, and possibly also the higher optic centers, by being in contact with a single axis-cylinder or neuron, which is the prolongation of a

[1] Anatomy and Histology of the Human Eyeball.

PLATE I



Diagrammatic Sketch of the Visual Pathway.

ganglionic cell. Cones eccentric to the macular region, on the other hand, do not have the individual communication, but a number of cones are in contact with a single axis-cylinder. This difference in anatomical structure accounts in part for the greater activity of vision of the macula over that of the peripheral retina.

Blood Supply of the Retina.—The outer neuron, or rod and cone layer, receives its nourishment from the choroid, *i. e.*, from the chorio-capillaris. The other

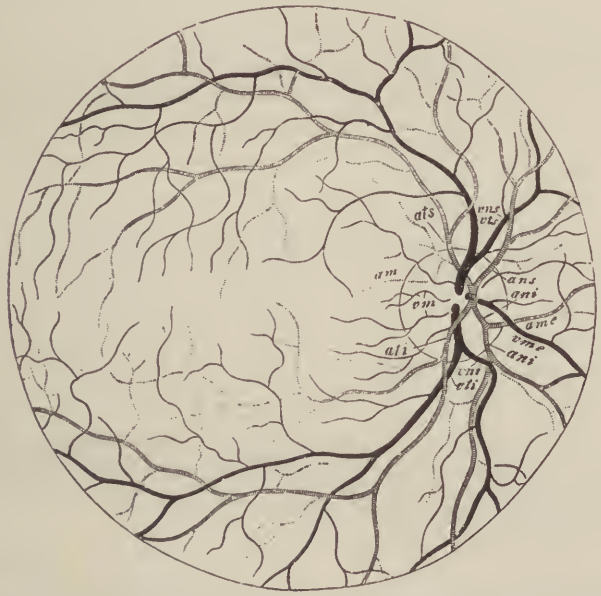


Fig. 2.—Distribution of the central artery of the retina. (Weeks.)

retinal layers are supplied by the main retinal branches of the central artery of the retina. The outer neuron, therefore, is distinctly separated in its blood supply from the middle and inner neurons, and is dependent upon the choroidal circulation for its activity. The great detour which the branches of the central artery of the retina must make in order to reach the extreme temporal region of the retina also has a bearing upon the early loss of the normal field in certain pathological conditions.

The Optic Nerve.—The optic nerve proper extends from the retina to the chiasm. It is about 5 cm. in length; 3.5 cm. of it is within the orbit, and 1.5 cm. is within the optic foramen and the skull. The part within the sclera, or the free intraocular end of the nerve, is known as the disc or papilla. Within the papilla the nerve fibers are non-medullated, but from the eyeball to the chiasm the nerve fibers are medullated throughout. The relative position of the fibers from the retina is maintained in the optic nerve; that is, fibers from the temporal region of the retina occupy a temporal region in the nerve; those from the upper part of the retina are in the upper part of the nerve, etc.[1] In fact, this arrangement is present in the chiasm, and as we shall see, to some extent in the cortex of the brain. The nerve is covered by three sheaths which are continuations of the brain coverings, namely, the dural, the arachnoidal, and the pial coverings. The dural, or outer covering, is a hard membranous tissue attached to the sclera, and in part is continued forward as Tenon's capsule. At the optic foramen it is closely adherent to the periosteum. Between the pia and the arachnoid, and the arachnoid and the dura, are the subarachnoid and the subdural lymph spaces. These are continuous with the same spaces within the brain, and in increased intracranial pressure these spaces are frequently distended with fluid, a factor which enters into the production of papilledema.

In the orbital cavity, the nerve lies loosely in the areolar tissue, but in the optic foramen, accompanied by the ophthalmic artery, it occupies rather snugly this bony canal. At this point also it is in close juxtaposition to the sphenoidal sinus, which is separated from it by a thin bony wall. These two points, the smallness of the bony canal or the optic foramen, and

[1] Fuchs has called attention to the fact that the peripapillary region of the retina is supplied by fibers which are located in peripheral parts of the optic nerve.

the proximity of the sphenoidal sinus, are predisposing factors in the easy production of retrobulbar neuritis. The analogue of this condition is found in the relation between middle-ear disease and inflammation of the facial nerve.

PAPILLO-MACULAR BUNDLE.—The optic nerve consists of numerous nerve fibers (estimated at 1,000,000) bound together in bundles. Centrally located, but indistinguishable in the normal nerve from the other bundles, is the papillo-macular bundle which furnishes us with a direct path between the macula and the

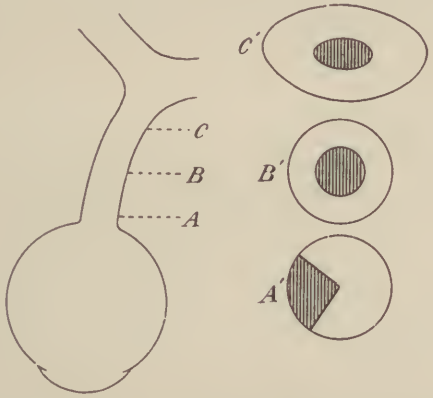


FIG. 3.—Diagram showing position and shape of the papillo-macular bundle of nerve fibers, *A'–B'–C'*, at the levels, *A–B–C* in the optic nerve. (Diagram suggested by Parsons.)

primary optic centers in the brain. In a normal nerve, these fibers are indistinguishable, but in certain forms of toxic amblyopia with central scotomata, degeneration of the optic tract has been traced from the eyeball up to the primary optic centers. From the primary optic centers the papillo-macular path to the cortical macular centers is not so clearly defined. That such a path does exist, however, continuing from the primary optic centers to the cortical macular centers has been established beyond any reasonable doubt. (See Special Pathology of Fields, p. 218.) The exact position of this macular bundle in the optic nerve is of some

importance. As it leaves the eyeball it is situated to the outer side of the nerve, but as it approaches the optic foramen it is fairly centrally located, a position which it maintains in the chiasm, where the fibers divide with the other fibers of the nerve, and in the optic tract as far as the primary optic centers. The shape of the papillo-macular bundle is also of interest. Just back of the eyeball it is triangular in shape and is to the temporal side. Midway between the eyeball and the chiasm it is round, and near the chiasm it is horizontally oval, about two to one. In the chiasm the oval appearance increases, and after it leaves the chiasm it again assumes a round form.

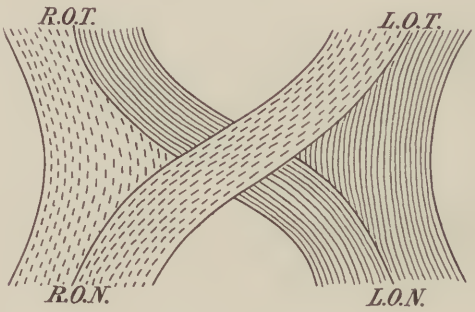


FIG. 4.—Diagrammatic sketch of optic chiasm, showing crossed and uncrossed fibers: *R.O.T.*, right optic tract; *R.O.N.*, right optic nerve; *L.O.T.*, left optic tract; *L.O.N.*, left optic nerve.

THE CHIASM.—About 1.5 cm. of the optic nerve lies within the skull. At this point the nerves unite to form the optic chiasm. In man the fields overlap, and binocular vision includes a large part of our visual field. The number of crossed fibers in the chiasm is therefore relatively decreased. The relation of the crossed and uncrossed fibers, according to Weeks, is three to two. According to Bernheimer the crossed fibers are located in the lower part of the chiasm, and the uncrossed fibers in the upper part of the chiasm.

The immediate anatomical environment of the chiasm is quite as important as the chiasm itself. It

is slightly above the groove of the sphenoid bone. Posterior to and beneath it is the sella turcica, in which rests the pituitary body. Directly in the posterior angle of the chiasm is the infundibulum, or process which connects the pituitary with the brain. Directly over the chiasm is the anterior tip of the third ventricle, and to either side are the internal carotid arteries. In this minute space, therefore, are many important structures which frequently become the seat of disease, and the optic commissure is usually involved.

Optic Tracts.—From the optic chiasm visual fibers pass along the optic tracts which are formed by the union of uncrossed fibers of one eye and crossed fibers from the opposite eye, including the papillo-macular bundle. The tracts bend around the outside of the cerebral peduncles and become a part of the midbrain structure as they pass into the primary optic centers, namely, the external geniculate body, the pulvinar, or the tip of the optic thalamus and the anterior corpus quadrigeminum. It is claimed that at least 80 per cent of the fibers of the optic tract pass to the external geniculate body. A matter of much clinical interest is the relative location of fibers which represent corresponding retinal points. Are they immediately brought together after leaving the chiasm, or are they indifferently placed in the optic tract without regard for their associated function? Up to the present time this point has not been definitely determined. In fact there is no positive assurance that associated fibers are brought into close contact before they reach the cortical centers in the cuneus. From our knowledge, however, of the orderly and systematic arrangement of fibers of the visual pathway, it is reasonable to conclude that they are in close contact immediately after they enter the optic tract. The clinical bearing which this anatomical relation may have upon homonymous hemianopsia, will be discussed at greater length under the head of Asymmetry of Fields in Homonymous Hemianopsia.

Primary Optic Centers.—*The External Geniculate Body, Anterior Corpus Quadrigeminum and Pulvinar.*—It is unnecessary for our purpose to enter into a discussion of the exact functions of these centers. From pathological studies it has been clearly shown that when the eyeball is removed, degeneration can be traced up to the primary optic centers and the centers themselves become atrophied. Experimentally, also it has been proven that a similar shrinkage of these centers occurs when the brain cortex in the region of the calcarine fissure on the same side of the brain is destroyed. The thalamus has functions other than that of vision. The tail, or pulvinar, undergoes atrophic changes in the conditions mentioned above, and this part of the thalamus at least is directly concerned in vision.

The anterior corpus quadrigeminum sends fibers to the nucleus of Edinger-Westphal in the third nerve and completes the light reflex arc to the pupil.

Communication of the Primary Optic Centers With the Motor Nerves of the Eye.—From the anterior corpus quadrigeminum, nerve fibers pass to the nucleus of Edinger-Westphal of the oculo-motor nerve. It is by means of these fibers that the reflex arc is completed, and stimulation of the retina by light brings about a reflex contraction of the pupil. According to Robert Bing[1] the pupillary reflex arc is composed of four sets of fibers: (1) From the retina to the anterior corpus quadrigeminum; (2) from the quadrigeminal body to the Edinger-Westphal nucleus; (3) from the Edinger-Westphal nucleus to the ciliary ganglion; and (4) from the ciliary ganglion to the pupillary sphincter. In group two, each quadrigeminal body sends fibers to both Edinger-Westphal nuclei. A ray of light thrown upon the retina not only causes direct contraction of the pupil of the homolateral eye, but at the same time causes a consensual contraction of the contralateral

[1] Compendium of Regional Diagnosis in Affections of the Brain and Spinal Cord, Second Edition, p. 193.

pupil. The integrity of or a break in this arc has, therefore, been used as a symptom of value in locating a lesion above or below the primary optic centers. If the lesion is above the primary optic centers, there is no interruption of the activity of the reflex arc and light

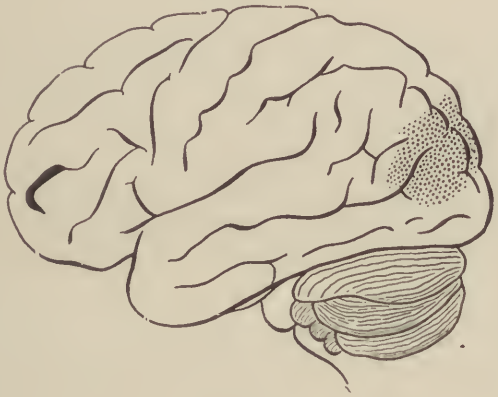


FIG. 5

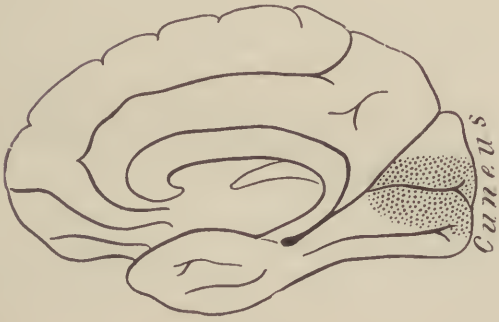


FIG. 6

FIGS. 5 and 6.—Diagrams showing higher optic centers in the brain. Fig. 5, the higher centers on the outer surface of the brain in the region of the angular gyrus. Fig. 6, the visual centers in the cuneiform body, mesial surface of the brain.

thrown upon the blind halves of the retinæ will cause pupillary contractions. If the lesion is below these centers there will be hemiopic pupillary inactivity—Wernicke pupillary inaction. (For the value of this sign see Hemianopsia.)

Paths to the Brain.—Tracing the paths from the retina to the primary optic centers has been much simplified as the result of diseased processes. Paths from the primary centers to the higher cerebral centers in the brain are attended with much difficulty. It is justifiable to conclude, however, from the numerous sources of information at hand, and making allowance for errors, that from the primary optic centers there is direct communication with the fore-, mid-, and hind-brain. These paths of communication are established through the optic radiation. The bundle of nerve fibers collected from the primary centers passes through the extreme end of the internal capsule, and thereafter spreads into a fan-shaped formation known as the optic radiation. So many reliable investigators have traced these paths that it is now generally accepted that a large number of fibers end in the cortical cells in and about the calcarine fissure. Others have been traced to the outer surface of the lobe as far as the angular gyrus. These latter so-called higher optic centers are without doubt an important part of the visual pathway in man. From our present knowledge, gained by experimentation and by studies in morbid conditions, we are led to believe that this is the area of psychic vision—a storehouse of memory pictures which aid us in properly interpreting and modifying the concept which is formed from the nerve impulses which are carried to the cells about the calcarine fissure. (See Plate II.)

The course and distribution of the optic radiation in its relation to the several areas of the posterior part of the hemisphere have distinct localizing value in disease. In the anterior part of the radiation, the close proximity of the motor and sensory paths explains the frequent association of motor and sensory disturbance on the side homolateral to the hemianopsia or contralateral to the lesion. In studying the course of the optic radiation, Meyer[1] was able to trace three distinct

[1] Tr. Assn. Am. Phys., 1907, 32, 7.

bundles or paths of fibers—dorsal, lateral and ventral. The dorsal and lateral fasciculi pass directly to the occipital cortex. The ventral fibers arch forward forming a loop, which extends as far forward as the anterior end of the temporal horn of the ventricle in the temporal lobe, then turn backward to the anterior part of the inferior calcarine cortex. Temporal lobe lesions may therefore be associated with hemianopic visual disturbances. A most important contribution to this phase of cerebral localization is that of Cushing in a paper read before the American Neurological Society in 1921.

Lesions in the occipital lobe as a rule produce complete or incomplete forms of homonymous hemianopsia without either motor or sensory phenomena.

THE CUNEUS.—The triangular body in the extreme posterior end of the hemisphere on the mesial surface, known as the cuneus, is now accepted as the location of the cortical visual centers. For a time there was some difference of opinion as to the exact extent of the visual area. It is now generally believed that the centers concerned with sight are within the area bounded by the line of Gennari. The area is divided by the calcarine fissure. This fissure is constant in man and is not one of the many irregular fissures which happen by chance to separate the convolutions. It is a sulcus of unusual depth and extends through the thin wall of the lateral ventricle, causing a distinct indentation in that lymph space, known as the hippocampus minor. Munk,[1] in experiments on animals, claimed that he "could map out the visual sphere in such a way as to represent the projection of the retina upon the brain."[2] It was thought possible that this claim was established upon insufficient data, but types of quadrantic hemianopsia which have been reported in literature tend to confirm these observations to this extent, that the upper parts of the retina are repre-

[1] Zur Physiologie der Gross-Hirnrinde.
[2] Hill, in Norris and Oliver.

sented in the upper part of the calcarine fissure, and the lower parts of the retina in the lower part of the calcarine fissure.

Studies of war injuries by Holmes and Lister[1] and others confirm these conclusions. These same studies also definitely locate the macular cortical centers in the posterior tip of the visual area on the marginal and inner lateral surface of each occipital lobe (Weisenburg). Peripheral parts of the retina are represented in the anterior end of the calcarine fissure, and intermediate parts of the retina between macula and periphery are represented in serial order from the posterior pole of the hemisphere to the anterior end of the fissure.

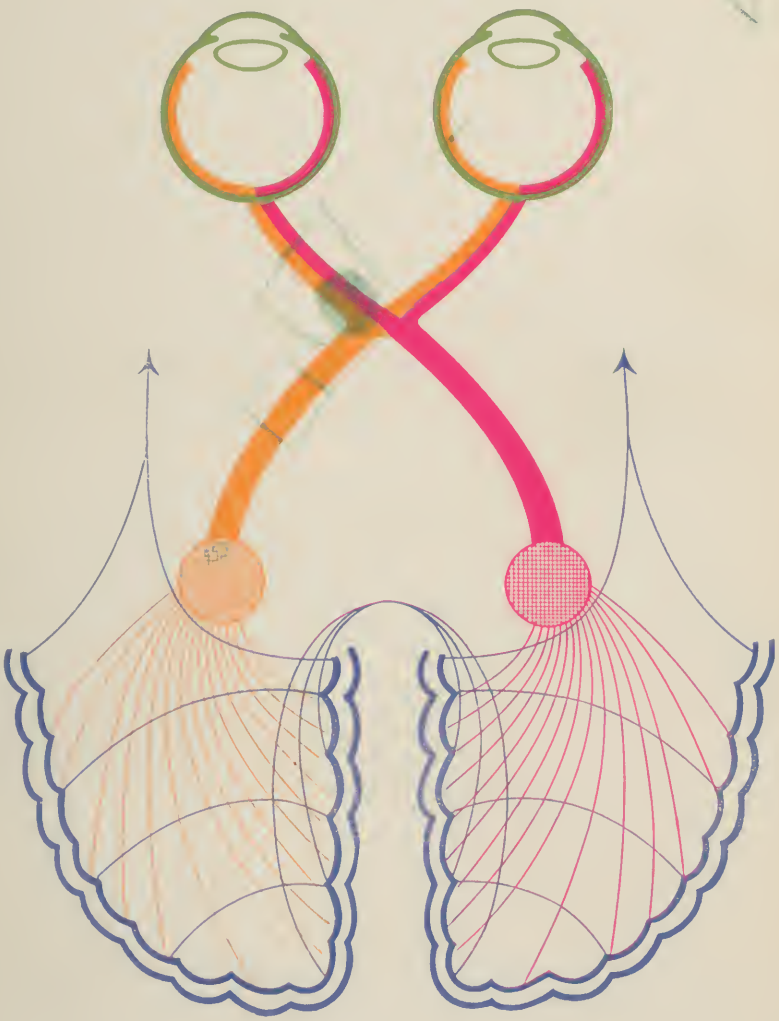
Macular Cortical Representation.—While it is definitely determined that the macular cortical centers are in the posterior tip of the hemisphere, the question of unilateral or bilateral representation has been much debated. The consensus of belief is in the form of bilateral representation. For example the right cortex represents macular vision on the right side of each retina and the left cortex that of the left side of each retina. A superficial lesion in the posterior tip of the right macular centers will produce a macular or minute central hemiscotoma in both visual fields to the left.[2]

Psychic Visual Centers.—Although Adolph Meyer, in his paper previously quoted, endeavored to show that the three segments of the optic radiation traced by him, were uniform throughout and therefore probably did not send fibers to the cortex around the angular gyrus on the outer surface of the occipital lobe, there is no doubt of communication between the visual centers in the calcarine cortex and the centers known as psychic centers. Lesions which intercept or cut off this communication are accompanied by mind-blindness. These centers are essential to and a part of the psychological phase of vision.

[1] Brain, 1916, 39, 34.

[2] Stewart: The Diagnosis of Nervous Diseases, 5th Ed., p. 38.

PLATE II



Diagrammatic Sketch of the Physiology of Vision.
(After Lohmann.)

GREEN—Physicochemical phase of vision.
RED—Physiologic phase or transformation of a light stimulus into a nerve impulse.
BLUE—Psychologic phase.

THE PHYSIOLOGY OF VISION.

Just what occurs in the visual act may be best explained by a study of Plate II, in which is graphically and beautifully represented the visual act in a diagrammatic sketch, as suggested by Lohmann.

He divides the act into (*a*) a physical phase, which the author has called a physico-chemical phase. This includes the dioptric parts of the eye and the receptive end-organs of the retina, or rods and cones sensitized by the visual purple. (*b*) The physiological phase, or that part of the optic tract from the rod and cone layer of the retina to the cortical or higher centers in the hemispheres, in which the light stimulus is transformed into a nerve impulse. (*c*) The psychological phase, which takes place in the cortex of the brain.

PHYSICO-CHEMICAL PHASE.—Perimetry is only indirectly concerned with the dioptrics of the eye. One must take into consideration refractive errors of considerable degree, as such errors, if not corrected, may interfere with the proper "taking" of the field. The purely physico-chemical act must, however, be thoroughly understood in order to correctly interpret abnormalities.

Accommodation.—The eyeball may be looked upon as a camera containing a dark chamber with an aperture in front—the pupil—the size of which may be controlled to meet conditions. Rays of light entering through this opening project upon the retina an inverted image. Through the medium of accommodation the image becomes sharply focussed upon the retina. This act of accommodation, or adjustment of the eye for varying distances, is brought about by contraction and relaxation of the circular fibers of the ciliary muscle. When the ciliary muscle is at rest, the zonule of Zinn tightens, and acting on the lens tends to flatten it. In this position in the normal eye parallel rays are focussed upon the retina. When, however, in the act of accommodation the circular fibers of the ciliary muscle con-

tract, the suspensory ligament, or zonule of Zinn, relaxes and the lens by its own elasticity and that of its capsule increases in its antero-posterior diameter—and objects nearer than infinity may be focussed upon the retina.

The Rod and Cone Layer.—To continue our analogy of the camera, the rod and cone layer of the retina may be regarded as the plate or film upon which the impression is to be made. The photographic plate is made sensitive to impressions by chemical processes. In the human eye similar conditions obtain, but the process is more complicated, as the chemistry of the body is always complex. The rods and cones must become sensitized. This is accomplished possibly by the "visual purple." It has been shown, for example, that the eye exposed for some time to an intensely bright light, sees nothing for a considerable period after being admitted to a dark room. The visual purple in this instance has been exhausted, and the eye is "non-adapted." After a time, the eye recovers "adaptation" and objects in a darkened room may be distinctly seen. The effects of light, therefore, upon the retina bring about a chemical change, or disorganization, which in time recovers itself. While not entirely beyond question, it is generally believed that the visual purple is the chemical substance upon which light acts and that it is the substance which renders the rods and cones sensitive.

Between this physico-chemical phase of vision and the purely physiological phase, a connecting link is necessary. A light stimulus must be converted into a nerve impulse. Just how or where this transition takes place is an unsettled problem and difficult to determine.

In the lower animals it has been shown that light thrown upon the retina brings about a shifting or change in the rod and cone elements. The rods become elongated and the cones become thickened. Such changes cannot be demonstrated in the human eye for obvious reasons, and it is generally thought that

changes of this character do not take place. A more important change in the retina caused by the light is the bleaching of the visual purple. At all events, there is evidence to lead one to believe that light produces a chemical change, either in the visual purple or in some other chemical substance which has the power of recovering itself. The cones do not contain visual purple. It is limited entirely to the rods. In the fovea, therefore, where only cones exist, there is no visual purple; and although this is the part of the retina in which acuity of vision is most marked, it is not as well adapted for night vision as other parts of the retina which contain rods. Lohmann therefore concludes, although not unreservedly, that the transforming of a light stimulus into a nerve impulse is probably a photo-chemical process. It is probable at least that the visual purple is an essential factor in this transformation.

PHYSIOLOGICAL PHASE.—Just where the physico-chemical phase ends and the physiological phase begins is equally interesting. Salzmann[1] divides the retina into three cellular layers: (1) The outer or rod and cone neuron; (2) the inner nuclear neuron; (3) the ganglionic neuron. We have discussed the first or outer layer. The physiological phase of vision probably begins with the second or inner neuron. The author believes it to be more accurately correct to speak of the inner neuron as the point of transition of the physico-chemical to the physiological phase. This would correspond to conditions as we find them in the spinal cord. The ganglionic cells would coincide with the ganglionic cells of the cord. The present tendency is to consider a neuron as consisting of a cell with a prolongation or axis cylinder. As to whether the nerve elements are in contact, as viewed by Ramón y Cajal, or the axis cylinder is a continuation of the cell, as claimed by Apathy and others, is unimportant for our purposes. Atrophy has been limited to any one of these neurons,

[1] The Anatomy and Histology of the Human Eyeball in the Normal State.

and this would tend to confirm the former theory. Little is definitely known about the exact functions of the inner nuclear layer, but all concede that this neuron serves as a connecting link of the various nerve elements, and processes of a high order take place within this layer. (Salzmann.) The third, or ganglionic neuron, therefore, we will regard as the actual beginning of the physiological phase of vision. It is in contact with the inner nuclear layer by short processes, and the axis cylinders extend from the ganglion cells to the primary optic centers at the base of the brain—the external geniculate body, the anterior corpus quadrigeminum and the tail of the optic thalamus. It is possible that this neuron is continuous even with the cortical cells in the cuneus. Studies of diseased or atrophic paths after enucleation have traced these parts as far as the primary centers—but so far as is known, we cannot say definitely that there is an uninterrupted path from the ganglionic cells in the retina to the brain cortex.

Light stimulus, which now has been transformed into a nerve impulse, travels along the axis cylinders, through the optic nerve, chiasm and the optic tract to the primary optic centers. After enucleation of the eyeball, and after removal of the occipital lobe, atrophic changes have been found in the external geniculate body and in the pulvinar, and to some extent in the anterior corpus quadrigeminum. A number of physiologists have failed to confirm these findings, but they have been observed by so many reliable investigators that we must conclude that these bodies or centers are directly concerned with the physiological phase of vision.

Tracing the various tracts through the brain has met with some difficulties, which thus far have not been entirely surmounted, and it will be best and less confusing to limit our discussion to what has been conceded as definite knowledge. Impulses travel through the optic radiation from the primary centers to the cortex,

in and about the calcarine fissure of the cuneiform body. Here the physiological phase ends and the psychological phase begins.

Psychological Phase —The visual centers of the brain, exclusive of the basal ganglia, are: (*a*) Those centers which are found in and about the calcarine fissure; (*b*) the psychic centers in the region of the angular and supramarginal gyri; and (*c*) centers for written and printed words in the left angular gyrus in right-handed individuals. These centers are connected as schematically illustrated in Plate II. The psychic centers act as a storehouse of all visual sensations received by the individual. They serve a larger purpose than that of memory. A nerve impulse carried to the visual centers in the calcarine cortex by the transmitting neuron in the physiological phase of the visual act must be interpreted in order to form a concept. Any new sensation is modified or rendered intelligible only by comparing it with former visual impressions. This is made possible by the psychic or concept centers. If the psychic centers are destroyed or communication between these centers and those in the calcarine cortex is interrupted, the individual is said to be mind-blind or as Munk puts it "psychically blind". The patient is able to see but has no memory pictures with which to compare his sensations. He looses the power of interpreting his sensations. Objects familiar to every one in daily life, under these conditions, loose their identity so to speak, and appear to the patient so afflicted as new and entirely unfamiliar to him.

A lesion which destroys the calcarine cortex produces blindness in homonymous halves of the fields. The patient is unable to see objects which fall in the blind halves of the visual field.

If the third group of centers is destroyed in the left hemisphere in right-handed individuals, there is an additional phenomenon, namely, alexia or inability to understand written or printed words.

The concept is formed in the occipital lobe. It is reasonable, however, to suppose that other parts of the brain may be concerned in the psychological phase of vision.

With this brief review of the generally accepted facts of anatomy and of the physiology of vision, we are prepared to take up the study of normal fields and of the field changes which take place in disease of the visual pathway.

PART II.

PHYSIOLOGICAL PRINCIPLES. NORMAL FIELDS.

Definition.—By perimetry is meant a study of central and of indirect vision, or that part of the field from which the eye at rest can receive impressions. By the use of the ophthalmoscope the observer examines and studies directly and indirectly changes which may take place in the media, the retina, choroid and sclera. Some of these changes are microscopical, and therefore open to direct inspection, while others are microscopical or so minute as to escape observation by the use of the ophthalmoscope. It is in this latter group of cases that a study of the projected field of vision, as determined by the practice of perimetry, is of particular value. On the other hand, gross fundus and media changes observed by the ophthalmoscope are confirmed and amplified by objective perimetry. In a study of diseases of the optic nerve, however, only gross changes, such as marked atrophy, may be observed by the ophthalmoscope. As atrophy does not manifest itself in the nerve head when the visual pathway is diseased above the primary optic centers, and certain retrobulbar intoxications are equally obscure, the ophthalmoscope cannot aid us in a study of such conditions. In fact its usefulness in optic nerve disease has its limitations.

It may be said, therefore, of perimetry that it is a valuable aid in the diagnosis of intraocular diseases and it is a *sine qua non* in the diagnosis of disease of the visual pathway, posterior to the eyeball.

Central and Indirect Vision.—Vision is of a twofold character: (1) Central, or that part which

allows the eye to fix on a small object, and (2) indirect or peripheral vision. When one fixes central or macular vision upon an object, it is possible at the same time to note with considerable detail objects situated remotely from the point of fixation. This is accomplished by indirect vision. The fovea in the macular region is regarded as the center of vision because of its great sensitiveness to clear perception. Visual acuity here reaches its greatest development, and it recedes rapidly in the area immediately surrounding the fovea and less rapidly beyond until the periphery of the retina is reached. Central vision notes details of objects at rest, but moving objects are observed with more accuracy by indirect vision. Similarly, although central vision is sharpest in good light, in peripheral parts of the retina, adaptation, or the ability of the eye to adjust itself to varying degrees of light, is more highly developed. It is therefore necessary to study both central and indirect vision in the normal individual in order to have a standard with which to compare pathological or diseased conditions. Perimetry is especially concerned in a study of the projected indirect field, although the macula and adjoining areas must also be studied carefully when central visual acuity has become impaired.

Visual Acuity.—The term visual acuity is especially applied to direct or central vision, although it is a relative term and may also be applied to indirect vision. By this term is meant either the ability of the eye to recognize minute points of definite size, as separate points at a definite distance, spacial perception, or to recognize a point of definite size at a definite distance. It has been variously estimated that the smallest point distinctly recognized by an emmetropic eye subtends an angle of one minute. Uhthoff makes it fifty-five and two-tenths seconds under the very best light and in good contrast. For perimetric purposes the central visual acuity of a given patient is expresssed by the usual formula, with the Snellen test card as the standard.

The numerator of the fraction designates the distance at which the letters subtend an angle of 5′, and the denominator, the smallest letters which the patient can read at this distance; or to transpose, the numerator is the distance at which the test is made, and the denominator, the distance at which the smallest letters read subtend an angle of 5′. This standard is arbitrary, but it is generally accepted. Central visual acuity therefore is the first fact to be determined in beginning a perimetric study.

The determining of the limitations of the visual field of indirect vision is accomplished first by entoptic study and second by means of perimetric instruments.

Entoptic Study.—Entoptic or subjective study of the projected field is made by the patient without the aid of instrumentation, and consists in the concentration of the patient upon his projected field before a background of uniform color. The noting of moving specks before the patient's eyes when caused by floating vitreous opacities is an example of simple entoptic study. To study the entire field phenomena, however, requires training of a high order, rarely possessed by an average patient. Perimetric studies are therefore of greater and more dependable value than entoptic studies, because the data obtained is the combined result of careful observation by the physician and to a less extent by the patient.

Laws of Projection and Direction.—In order to understand the relation of points in space to points in the retina a study of the laws of projection and direction is necessary.

When a visual impression is made upon the retina the image is not observed on the retina itself but is seen in space.[1] A similar phenomenon is observed in the sensory nerves of other parts of the body; for example, one of the earliest symptoms of hip-joint disease is pain on the inside of the knee; the pain of pneumonia may be referred to the iliac region of the abdomen, etc.

[1] See Tscherning's Physiologic Optics, p. 304.

The exact point in space to which this visual impression is referred and is seen is partly determined by the law of direction and partly by the law of projection. In Fig. 7, a ray of light passing from a point (*a*) in space through the nodal points of the dioptric system falls upon the point (*a'*) on the retina. It is not seen here but is projected outward along the same line and is seen as coming from (*a*) in space. The same relationship can be established between (*b*) in space and (*b'*) on the retina, (*c*) and (*c'*). What is true of these three points and their correlated points on the retina is equally true of every point in space within the range of

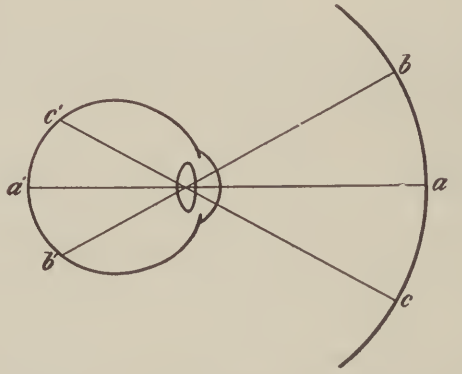


FIG. 7.—Diagram illustrating the laws of projection and direction.

retinal sensitivity. The laws of projection and direction, therefore, establish the fact that every point in the projected field has a correlated retinal point. The clinical application is as follows: the upper part of the retina receives impressions from the lower part of the field and *vice versa;* the right half of the retina receives impressions from the left field and the left half from the right field. In perimetry the defect of the field is recorded and not the location of the lesion. It is always necessary to transpose if one wishes to visualize mentally the location of the lesion.

CORRESPONDING RETINAL POINTS.—As each point in the projected field bears a definite and fixed relation

to a point in the retina, every point in one retina has a corresponding and definitely related point in the other retina, and these points are known as corresponding retinal points.

In order to understand the relation of corresponding retinal points, the reader is referred to the anatomy of the visual pathway. The higher visual centers are located in the cuneus of each hemisphere. The fibers from the right cuneus are collected into a bundle known as the right optic tract. In the chiasm the tract divides; the uncrossed fibers pass forward to the outer half of the right eye, and the crossed fibers pass over to the left eye and supply the nasal side of the left retina. A similar distribution of the left cuneal

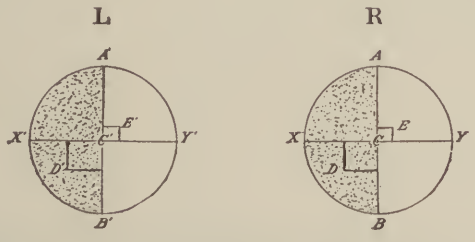


FIG. 8.—Diagram illustrating corresponding retinal points. (Hansell and Reber.) (Courtesy of P. Blakiston's Son & Co.)

fibers supplies the outer half of the left and the inner half of the right eye. This arrangement brings homonymous parts of each retina into definite and fixed relation. An image in space which falls upon corresponding retinal points makes an impression upon both retinæ, but the resulting impressions form but a single image.

What is true of corresponding retinal points is true also of larger parts of the retinæ, as quadrants and halves of the retinæ. For example, in Fig. 8, the quadrant $X'\ C'\ A'$ of the left eye corresponds to the quadrant $X\ C\ A$ in the right eye. $A'\ X'\ B'$ half of the left retina corresponds to $A\ X\ B$ of the right retina, etc. The fields of each eye are taken separately; therefore,

in disease of the intracerebral portion of the visual pathway the relation of the corresponding parts is important. As will be shown in the study of general pathology of fields, the dividing line between retinal halves may not always be a perpendicular line, but it may be oblique. The obliquity, however, will always be the same in each eye.

Factors Which Influence the Size and Shape of the Normal Field.—These determining factors may be discussed in two groups: first are the anatomical limitations and variations, which are inherent and peculiar to an individual; second is the laboratory technic in which physical and physiological principles play an important role.

Anatomical Factors.—In order to outline the extent of a field of a given patient and to establish a standard for comparison, the perimeter is employed, when the measurements are made, as it were, in a hollow hemisphere, all points examined being equally distant from the eye, or the measurements are made on a flat surface known as a tangent screen or campimeter. Measurements on these instruments have established a "standard visual field" which is approximately oval in shape, as shown in Fig. 9.

The extent of the retinal area capable of receiving impressions of form and color should determine the size of the projected field. Other factors, however, influence the size and the shape of the field to as great an extent as the activity of the retina. The position of the eye in its bony socket has a direct bearing upon not only the size but also the shape of the form field. In Fig. 9 the shape and size of the average field for form is graphically represented. One notes that the field of each eye consists of an irregular oval, the greatest extent being toward the temporal region, and the narrowest part of the field down and to the nasal side. This shape is largely determined by the position of the eyeball in its bony socket.

Bony Prominences of the Face and the Shape of the Orbital Cavity.—Temporally there is no obstruction to the rays of light falling upon the nasal retina as far forward as the convexity of the cornea, the size of the pupil, and the physiological activity of the forward part of the retina will permit. To the nasal side the field is limited because of the inability of the forward part of the temporal retina to receive impressions by reason of the prominence of the nose. The prominence of the bony orbit above limits the upper field; the lower field is obstructed in a similar manner, but to a less extent.

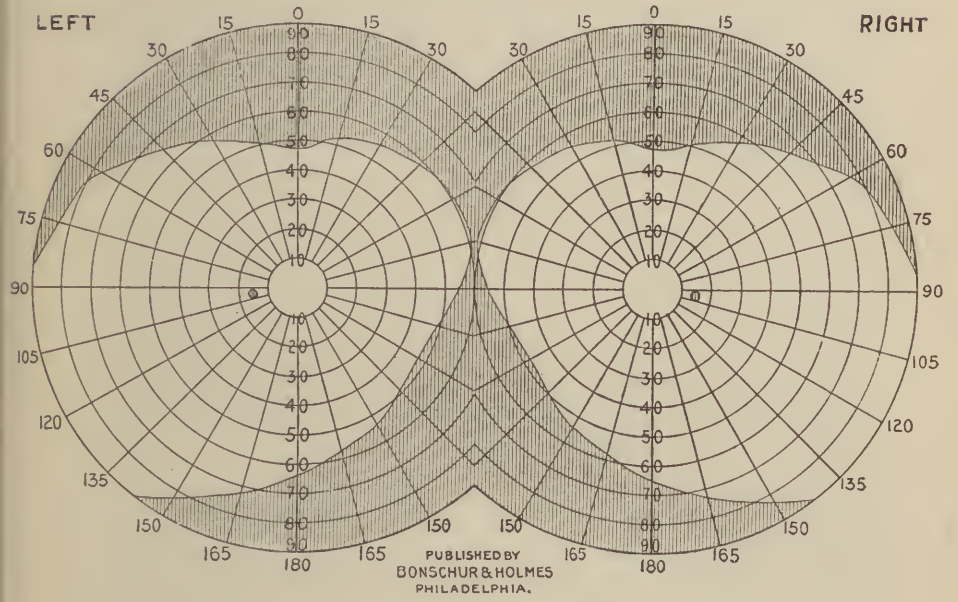


FIG. 9.—Normal form fields.

Activity of the Retina.—The extreme forward part of the superior and nasal retina is functionally more active because of its almost constant use in our habit of looking down and out in orientation, whereas the inferior and temporal parts of the retina are less constantly used and consequently less sensitive to impressions.[1]

[1] It is probable that the nasal retina is more sensitive to stimuli than the temporal retina because of our special need, rather than the result of great use.

Two factors, therefore, are largely responsible for the shape and size of the form fields: (1) The bony conformation of the orbital cavity and the face, and (2) the great activity of the superior and nasal parts of the retina. Other anatomical factors which play a minor role are:

1. *The Width of the Palpebral Fissure.* — This will determine in some instances the extent of the fields altitudinally.

2. *The Size and Plane of the Pupil.* — A large pupil will allow rays to fall farther forward on the retina than a contracted pupil. The plane of the pupil as influenced by the depth of the anterior chamber likewise contributes. A shallow chamber enlarges and a deep chamber tends to contract the field.

3. *Refractive Errors.* — Myopia, because of its long axis and the greater distance of active peripheral parts of the retina from the pupillary plane, tends to diminish, whereas, hypermetropia tends to increase the field.

4. *Forward Attachment of the Retina.*—It is claimed (Wilbrand, in *Norris and Oliver*) that the retina is attached farther forward on the nasal side than temporally. This, however, is not so important a factor in the greater extent of the temporal field as the absence of obstruction from bony and soft orbital tissues on the temporal side. The great extent of the temporal field is due also to the activity of extreme forward parts of the nasal retina. It is constantly in use, and therefore more receptive to visual impressions than the temporal half.

Factors in Technic.—1. *Intelligence of the Patient.* —The degree of the intelligence of the patient is important in measuring accurately the extent of the field. Taking the fields of illiterates rarely does justice to such patients, because of slow mental processes and their difficulty in understanding just what is required of them. Ordinarily, to obtain accurate results in this latter class of cases it is necessary to repeat the measurements several times. Each measurement will show

slight enlargement. This observation is also true to some extent even in the most intelligent, as a better understanding of what is required is obtained after one or two examinations.

2. *The Influence of Drugs.*—Strychnia is a well-known nerve stimulant; it increases reflexes and nerve activities throughout the body. In the peripheral parts of the retina there is a zone in which rods and cones, because of little use, and being few in number, require strong stimulation in order to arouse definite impressions. Strychnia acts as a sensitizer to this zone as well as to all functionating parts of the retina, and therefore increases the size of the field temporally.

3. *Fatigue.*—In contrast to the stimulation by strychnia is the sedative influence of normal fatigue, not the result of neurasthenia. Examination should be made when the patient's physical and mental conditions are good, and not at the end of a prolonged general eye examination. If the patient is examined when suffering from physical or mental tire, the fields obtained will show a contraction which is abnormal for that individual patient. In functionally abnormal and organic processes, this factor is of great importance, as a type of field is developed which may be regarded as pathognomonic of certain and definite pathological states.

4. *Effect of Light.*—The character and intensity of light has a direct bearing upon the size of the form and color fields, and particularly the latter. In order to obtain the maximum form field good illumination is necessary. This is difficult to secure in the average office, and under the most favorable conditions, if daylight is employed, the patient's body will cast a shadow which necessarily makes the diffusion of light unequal. The latest model of an illuminated perimeter overcomes this difficulty. This perimeter, modelled by Ferree and Rand will be discussed in Part III. For practical use, therefore, artificial daylight will best serve the purpose with a minimum amount of error. The better adaptation for varying degrees of light *of peripheral*

parts of the retina, over that of the macular region has been established. The form field is not influenced in normal conditions to any great extent by slight variations of light. In pathological states, however, the intensity of light has a direct bearing, and in order to obtain uniform results the best possible light should be used. Although form fields vary little unless the light is very much diminished, the behavior of the color fields is influenced by even slight differences in the intensity of the light. It is probable that the variation in the size of the color fields given by different observers is due largely to the conditions under which the fields are taken. In functional night blindness and in beginning optic atrophy this tendency for the color fields to contract under diminished light is accentuated. It is therefore important at all times to measure the fields with standard illumination.

5. *Intensity and Character of the Stimulus.*—A fuller discussion of the effect of this and the following factors, on the size and shape of the field, will be found in the chapter on Technic. It is important to note here, however, that the character and the intensity of the stimulus have quite an important bearing upon both size and shape.

6. *Preëxposure and Surrounding Field.*—The brightness of the surrounding field, and the brightness to which the retina under study is preëxposed before the stimulus is applied, have always been regarded as factors which might have some bearing upon field studies. The tremendous importance of taking into consideration these factors and the reasons for the same, have but recently become thoroughly understood. They, together with fixation, etc., will receive due consideration in the chapter on Technic.

Size of Color Fields.—Physiological studies of the behavior of colors in testing retinal sensitivity necessitate a revision of our former conclusions. Ferree and Rand in exhaustive studies have been able to show varying degrees of sensitivity to form and color stimuli

from macula to the periphery, in the meridians studied by them. They furthermore demonstrated that the peripheral retina is sensitive to red, blue and yellow to the extreme limits of the form field. Green falls far short of these color limits. Their work was done under ideal laboratory conditions with spectrum colors and with much accuracy. In order, however, to arouse definite color sensitivity in the peripheral retina, the intensity of the stimuli was increased to a maximum amount, far in excess of clinical possibilities. Their conclusions are in accord with clinical facts and laboratory findings of which we had some, although perhaps inconclusive, knowledge in the past.

It is manifestly impossible, however, to hope to obtain clinically the accuracy in technic which they were able to employ. With the Ferree-Rand perimeter and others modified and modelled after the Ferree-Rand model, laboratory methods are reduced to a practical basis, with the following results: (1) The limits of any color field will not show the even outline as ordinarily seen on the average chart such as in Fig. 60. The boundary on the contrary is more or less irregular because of the difference in retinal sensitivity in different meridians. This irregularity varies with the individual and even in the two eyes of the same individual; (2) the limits of the green field are always found within the limits of the red; (3) each color field enlarges or contracts by varying the foot-candle power of the illumination from 0.03 to 51; (4) variations increase as the illumination diminishes. With an average illumination of 7-foot candle power, usually obtained on the Ferree-Rand perimeter, and reproducible in any office, the red and blue in 35 normal individuals showed the following average: Upward, 32 to 35 degrees; downward 40 to 42 degrees; nasally, 40 to 43 degrees; and temporally, 60 to 62 degrees. Green measurements were as follows: Upward, 22 degrees; downward, 25 degrees; nasally, 26 degrees; and temporally, 38 degrees.

Working with 1 degree test object and Heidelberg

papers, instead of Herring papers, which Ferree and Rand used, the author has failed to find interlacing between the red and blue fields. The author's experiments were conducted with due care, standard illumination, and with regard for preëxposure and surrounding field. The difference in the results is probably due to the difference in the pigments employed. Wilbrand and others have pointed out that colors, as they pass from periphery to center, give the sensation of being mixed with black and white, and therefore appear in varying shades before full saturation takes place and the color is recognized by the patient. This is particularly true of red and of green. This fact will naturally give rise to discrepancies. It must, however, be reckoned with clinically because the phenomenon is accentuated in pathology.

The field limits as ordinarily found in text books vary much and for the most part are in excess of Ferree's figures. This is due to the fact that the stimulus employed is larger, and to a lack of uniformity and conformity to proper standardization of technic.

Average field limits as found by the author are as follows:–

	Up.	Down.	Nasal.	Temporal.
Blue	26°	38°	35°	54°
Red	21°	28°	27°	41°
Green	18°	22°	23°	26°

It is not likely that the work done in clinic and office can be done in the same painstaking manner as that shown in Ferree's studies. Due allowance should be made for errors which will necessarily creep into hurried clinical work, especially as field studies are made upon patients from all walks of life and in varying degrees of health. The figures given in each instance as a minimum in the author's table may safely be accepted as normal on the minimum side.

Mariotte's Blind Spot.—The optic nerve enters the eyeball about 15 degrees to the inner side of the macula, and a little above the horizontal plane of the

macula. In the nerve head, or papilla, the visual perceptive organs, the rods and cones, are not in evidence. This area is therefore blind to all forms of visual impressions, and it gives rise to a blind spot or scotoma in the visual field, known as the blind spot of Mariotte. In the charted field, therefore, it is about 15 degrees to the outer side and a little below the center of fixation.

Van der Hoeve[1] found in the examination of 100 young adults a blind spot which averaged 7 degrees vertically and 5 degrees in horizontal diameter. He, with Haycroft and others, also found an area surrounding the blind spot in which color perception was not possible. The author's studies confirm these observations as to the size of the blind spot. The inner margin of an average normal blind spot is 13½ degrees from central fixation, 5 degrees in width and 7 degrees in length, and extends 2 degrees above the horizontal and 5 degrees below the horizontal meridian.[2] It varies more frequently in normal limits in the vertical diameter than in the horizontal. In numerous cases examined and in a study of his own blind spot the author has found that color limits as well as form limits are sharply defined in good light. The normal indistinct zone surrounding the blind spot is difficult to detect. Only refined technic can elicit it. When such a zone is obtained by average methods, it may be looked upon as suspicious evidence of a pathological condition, which more careful analysis may verify.

Normal Binocular Fields.—The normal field thus far described is that of a single eye. In the lower vertebrates the eyes are placed in the sides of the head, and there is no overlapping of the fields of the two eyes. As we ascend in the scale of the animal kingdom the

[1] Arch. f. Augenh., vol. 70, 158.

[2] Exact measurements are 7° 40′ in vertical axis, and 5° 28′ in horizontal. Average distance from fixation center to the center of the blind spot is 15° 49′. See Perimetric Studies of the Normal and Pathological Blind Spot of Mariotte, by L. C. Peter, Trans. Am. Acad. of Ophth. and Oto-laryng., 1915.

eyes are placed farther forward in the head, and in the higher mammals the fields of vision overlap. In man this overlapping reaches its highest degree.

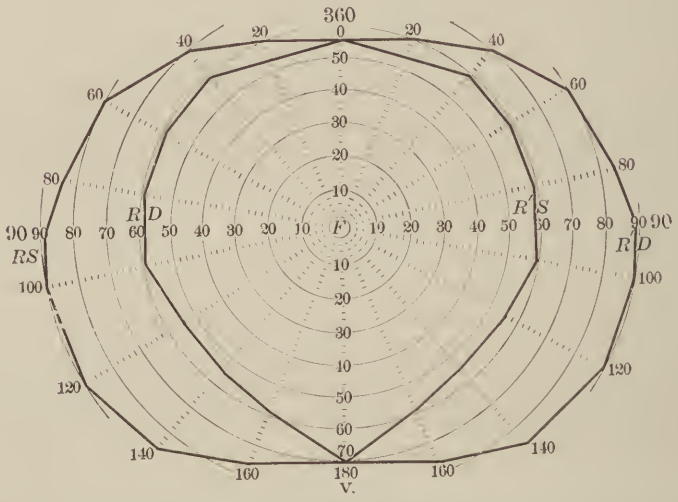


Fig. 10.—Binocular fields. (From Wilbrand and Saenger, after Förster.)

Fig. 10 represents a normal binocular field; that is, a field taken with both eyes open and fixing on the same object. The central clear space DR' outlines the overlapping of the fields for form. RS–D represents indirect vision of the left eye alone and S–$R'D$ that of the right eye. Measurements of the binocular fields are rarely made. They are not of great clinical value aside from the enlargement or contraction obtained in divergent and convergent strabismus.

PART III.

AUTOPERIMETRY AND PERIMETRY—METHODS—TECHNIC OF FIELD TAKING. INSTRUMENTS—CHARTS.

Entoptic study, or the investigation of the fields by the patient, is a complicated process, and is attended by much inaccuracy. It is of little scientific value unless the observer is a physician or is conversant with the subject-matter under discussion. A patient may see an opacity in the media, the lens or vitreous, and may be able to sketch such opacity with a fair degree of accuracy. Technically, however, this auto-study of changes in the media should not be included in perimetry. Intelligent patients may be able to make fairly correct drawings and paintings of the phenomena and the play of colors which they observe subjectively in scintillating scotoma of migraine, and it is not unusual for a patient to give fairly accurate descriptions of positive scotomata in chorio-retinal disease. The complexity, however, of the mental act of determining the limitations of the fields of peripheral vision without instruments is rarely dependable. Furthermore the value of perimetry lies especially in the charting of observations made by various methods of examination, for preservation and future comparison, and nothing short of instruments of precision should be employed.

Methods of Taking Fields.—Three methods of studying the field may be employed, each with its special adaptation for particular phases of perimetric investigation: (1) The hand method; (2) examination by means of a perimeter; (3) examination by means of a campimeter or tangent plane.

Hand Method.—This is the oldest method used, the observer's own field serving as a standard with which to compare the field under investigation. The patient is seated in front of and facing the observer, at a distance of about two-thirds of a meter, or at arm's length. If, for example, the right eye is under study, the observer covers, with his own hand, the patient's left eye and asks the patient to fix his vision on the operator's left or open eye. The operator's disengaged left hand is now moved from the extreme periphery of vision towards the line of central vision, midway between the patient and himself. When the patient is conscious of the operator's hand within his range of peripheral vision, he immediately makes it known according to the instruction received before the study is undertaken. This is done in the four cardinal directions, and at other points if necessary, and the results are compared with the operator's ability to recognize the same object. Using his own field as a standard, any marked cutting or shrinkage in the patient's field may be noted. Although crude and at best an approximate test, it may be reduced to greater refinement by using a small white test object, a piece of white paper for example, to roughly outline the form field. It is not suitable for even approximate color studies. Cognizant of its crudeness, it, nevertheless, has a distinct role in routine studies, in cases in which there is an appreciable shrinkage or as a preliminary study to a more accurate investigation by the other methods to be described.

It has a wide range of applicability under the following conditions: (1) It is a quick method of determining the presence of marked contraction, the exact extent of which may be measured on the perimeter or campimeter; (2) in hemianopsia it is a good method for class demonstration; (3) for bedside work and home use, when a perimetric examination is not feasible, the hand method may be employed; (4) when examining illiterates, feeble-minded or people of alien tongue, approximate information may be obtained by this method;

(5) a modification may be employed in the examination of semicomatose or partly conscious patients if the winking reflex is preserved. In these cases a small electric light or candle may be employed. In applying the method one looks for the reflex winking of the lid when the patient becomes semiconscious of the bright light in the field of vision. It is necessary to observe care in holding the light at a sufficient distance from the patient so as not to excite actinic sensibility instead of that of light. Unconscious seizures, due

FIG. 11.—Hand method of taking fields.

to thrombosis, hemorrhage and embolism are common occurrences in adults of fifty years or older; and hemianopsia is a frequent accompanying symptom in these cases, although often of short duration. In this type of case, therefore, this method may be employed to determine the presence or absence of hemianopsia. (6) the light projection of a mature cataract case may also be taken in a dark room in a similar manner, by using a small electric light, such as is employed in the various types of luminous ophthalmoscopes. More accurate work may be done by suitable modification

on the campimeter, or in the absence of the latter, a fair degree of knowledge of the patient's light projection can be obtained in this manner; (7) when the fields are cut to any great extent in chronic glaucoma and central vision is reduced by corneal haze, this same method may be applied to roughly determine the amount of shrinkage in the fields.

While a helpful method in routine examination of a patient, especially when pressed for time, as in hospital work, the author wishes again to emphasize the fact that this hand method is only approximately correct, and should be followed by one or both of the more accurate methods about to be described.

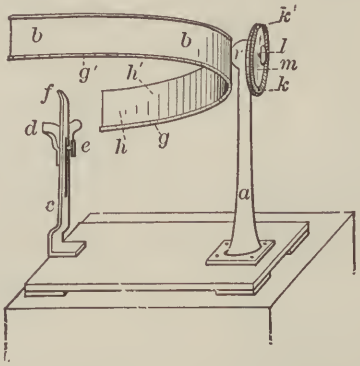


FIG. 12.—Förster's perimeter. (Norris and Oliver. Courtesy of J. B. Lippincott Co.)

The Perimeter.—Although the last of the instruments for studying the field to be adopted by the profession, the perimeter easily takes first rank in popularity. Its value in delineating the proper boundaries or silhouette of the field, in its present improved model, the Ferree-Rand perimeter, is recognized by all. For this purpose, the examination should be made if possible in a hollow sphere so as to subject all parts of the retina to like conditions. The perimeter, therefore, as devised by Förster, and copied in all essentials by other models, meets this condition. It consists of an arc of a

circle 180 degrees (*b*, *b*), supported by the arm *a*, and made to revolve about the pivot at *r*. The semicircle is made with a radius of 33 cm., or 13 inches. On the outside of the semicircle *b*, *b* are recorded the degrees so as to admit of a ready reading. The surface of the plate *m* is divided into meridians. It moves with the semicircle and the meridian along which the measurement is made can be read off from the surface *m*. A chin rest is provided for support (*d*) at a point 33 cm., or 13 inches, from the center of the arc *b*, *b*. This chin rest can be raised or lowered so as to bring the eye under examination over the point *f*. The point *f* is stationary, and is on the same level as the fixation-point on the arc. The perimeter is supported on a table which can be raised or lowered to suit the patient's height. The same result can be obtained by a stool which can be raised and lowered.

Many modifications of this perimeter have been designed, but the essential principles have remained unchanged.

The Campimeter or Tangent Screen.—The blackboard, or tangent screen method of study was introduced by von Graefe. In this instrument, the arc of a circle is replaced by a flat surface or tangent to the arc, for the purpose of studying changes which develop in the central or paracentral areas of the field. The von Graefe board consists of a blackboard, 3 by 4 feet in size, divided into squares of 3 inches each, Fig. 13. Like the Förster perimeter, this original model has undergone many changes and variations, to meet the needs of the various designers of new models. In several models, such as the Duane tangent screen, Fig. 23, and the Elliot scotometer, Fig. 29, only a plain black cloth without tracings is presented to the patient's eye. In other types, such as the author's hand campimeter, Fig. 26, and the Bishop Harman scotometer, the tracings as found in Fig. 25, are placed on the screen, while the chart for the Lloyd stereo-campimetric slate is designed as in Fig. 95.

Perimeter and Campimeter Compared.—In order to quickly grasp the particular value and the limitations

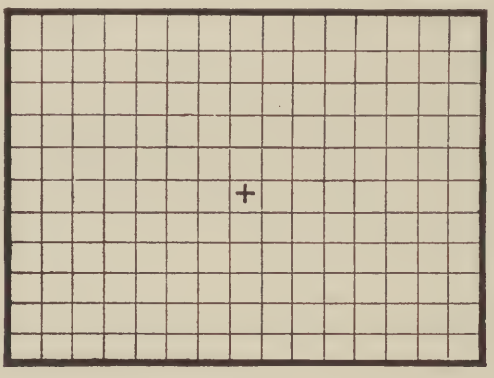


FIG. 13.—Von Graefe form of campimeter.

of these two methods of field study the principles of construction are graphically presented in Fig. 14 and 15. In Fig. 14, L. F. O. represents the arm of the

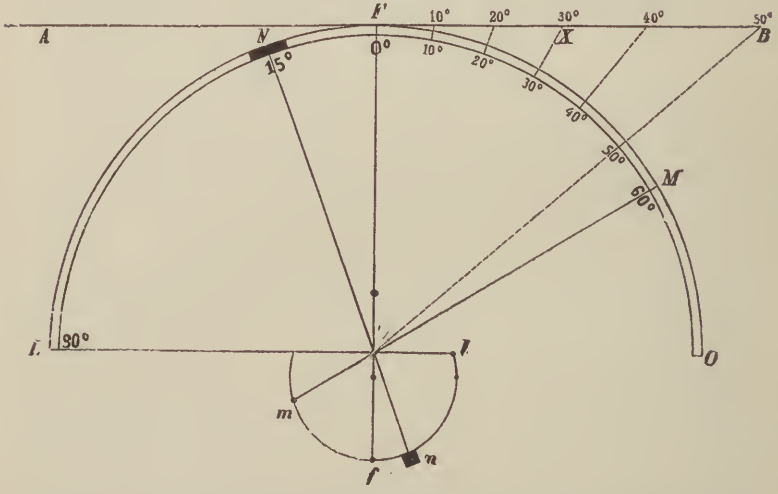


FIG. 14.—A diagram showing the relation of a tangent campimeter to an arc perimeter. (Weeks.)

perimeter, and A. F. B. the tangent plane or campimeter. It is apparent that the length of the radii in the

arc L. F. O. is always the same, and second that 10, 20, 30 and 40 degrees are equally distant from each other on the arm of the arc just as their angles of separation are equal. On the tangent plane each radius naturally

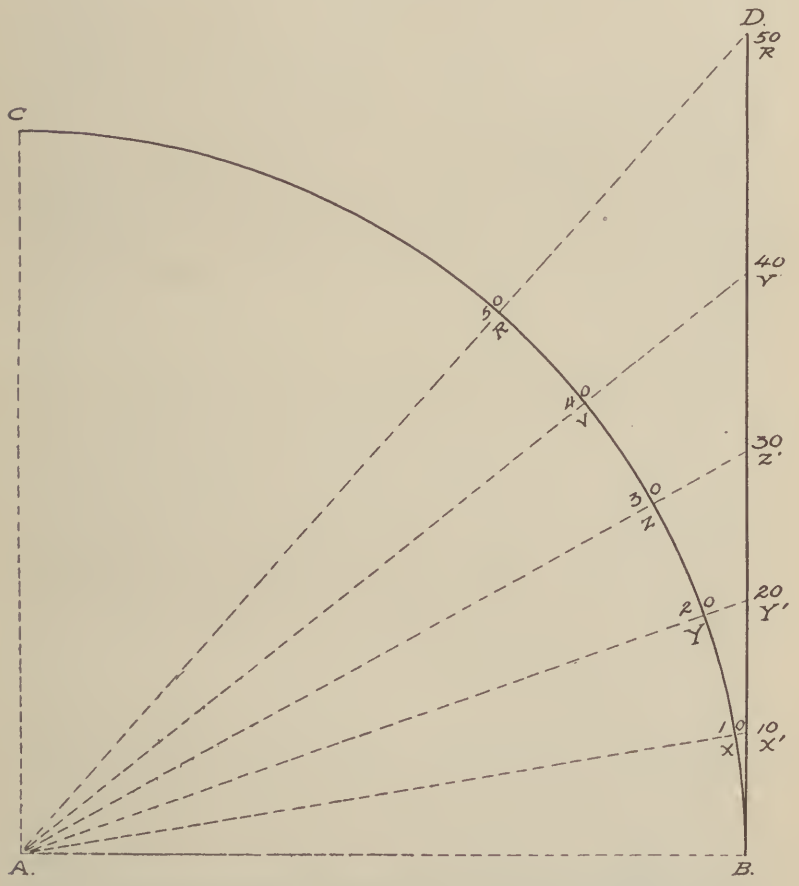


FIG. 15.—The author's diagram showing the relations of the tangent to the arc perimeter.

increases in length from the center to the periphery and the distance from F to 10 degrees, 10 to 20 degrees, etc., also increases. While these differences are not marked up to 30 degrees, the error increases rapidly beyond this, and for practical purposes the campimeter loses much

and results are only approximately correct beyond the 30 degree circle. From a standpoint, therefore, of practicability and accuracy the tangent plane ceases to be of value beyond 30 degrees from the point of fixation. Were it not necessary, in field studies, to take into consideration other factors, there would seem to be little merit in a tangent plane for any part of field studies, as the perimeter would seem to be sufficient for all purposes. Other factors, however, need very careful consideration.

Aside from the question of illumination and the problems involved in the proper control of the stimuli, one feature of the tangent plane makes this method of study indispensable for good work, namely *elasticity*. Mechanically operated instruments work in grooves and channels. This is true of the perimeter, and what is advantageous in determining the peripheral limits of vision becomes cumbersome and unsatisfactory in studying central defects. Central changes are for the most part minute blind areas. In order to definitely outline these areas between and including the point of fixation and the blind spot of Mariotte, a flat surface and a flexible stimulus are most essential for good work.[1]

In fact, it is now generally accepted by all who have made a study of the subject, that the perimeter in its present improved form, operated under standard conditions, is essentially adapted to the outlining of peripheral field limits, and the tangent plane is the instrument of choice for central defects. The tangent plane might be called a scotometer. This term, however, is too narrow, as the instrument is equally useful for any form of study in the central and paracentral field. To state specifically and concisely, therefore, the special role of the three varieties of methods of perimetric study, the hand method should be employed as a

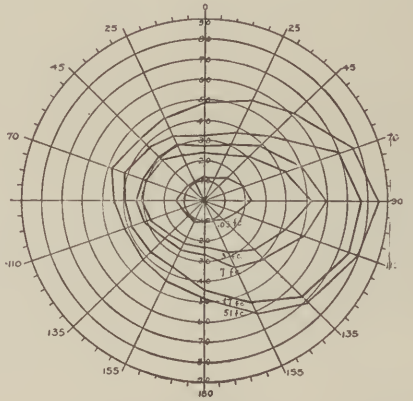
[1] For a more detailed study of this phase of the subject, the reader is referred to the Value and Limitations of Perimetric Methods of Study, by the author, Am. Jour. of Physiologic Optics, January, 1920, 1, 56.

rapid routine means of preliminary study of cases which seem to show gross defects of peripheral limits; the perimeter is essentially adapted to accurate measurement of the peripheral field; and the tangent plane is the instrument for careful analysis of central and paracentral defects.

General Technic of Field Taking.—In order to be thoroughly qualified to appreciate the advantages and disadvantages of the many instruments which are offered for use in perimetry, certain general principles or determining factors in field taking which have recently been found to be most essential, should be presented. It is by attention to these principles that a new and worthwhile technic has been evolved, a technic which has made the reproduceable field of real diagnostic value. While many writers, physicists and clinicians have contributed many detached fragments of evidence, it has remained for Drs. Ferree and Rand to point the way to the elimination of much of the variable element in field studies, a variability which has minimized the value of perimetry in the past. In our struggles from day to day to reproduce the same results, and our failures to accomplish the same, the variations due to true pathological or functional changes in the visual pathway have been obscured by variable factors in technic, most of which are correctable. The more important of these factors are illumination, preëxposure of the retina under investigation, surrounding field, intensity of the stimuli, and fixation.

Illumination.—Of the correctable factors which contribute most variability, illumination is not only the most important but perhaps the best understood. It is impossible in any climate to obtain uniform illumination at different times of the day or of the season when natural daylight is employed in perimetric work. If a white stimulus is used on a black background, variations in the size of the form field are not so marked under varying differences in the illumination during the day. When, however, colored stimuli are employed

the variations are great. In Fig. 16 are recorded by Ferree and Rand,[1] the blue fields taken under 51, 17, 7, 3-foot-candles of light, illuminations equal or equivalent to the variations found between 1 P.M. and 4.15 P.M. on a bright day, January 14, 1921. A difference of from 13 to 37 degrees was found for blue. Red varied from 11 to 37 degrees, while green varied from 10 to 19 degrees. This incontrovertible evidence clearly eliminates daylight as a constant and dependable form of illumination in field taking. Variations equally striking might be found in artificial illumination if it were



Fields for blue.

FIG. 16.—Showing variations in both the extent and the shape of the color fields when taken under 51, 17, 7, 3, and 0.03-foot-candles of light. (Ferree and Rand.)

not for the "daylite" filters which can be purchased on the open market. While the different filters offered may not be exactly the same, there is sufficient uniformity in all of them to be adopted for perimetric purposes. These essentials are, they should be fairly constant and other sources of illumination should be cut off in the perimetric room. If the dark room is used and the perimetric field is illuminated by one or more "daylite" filters, the results for an individual

[1] Trans. of an International Congress of Ophthalmology, 1922.

PLATE III

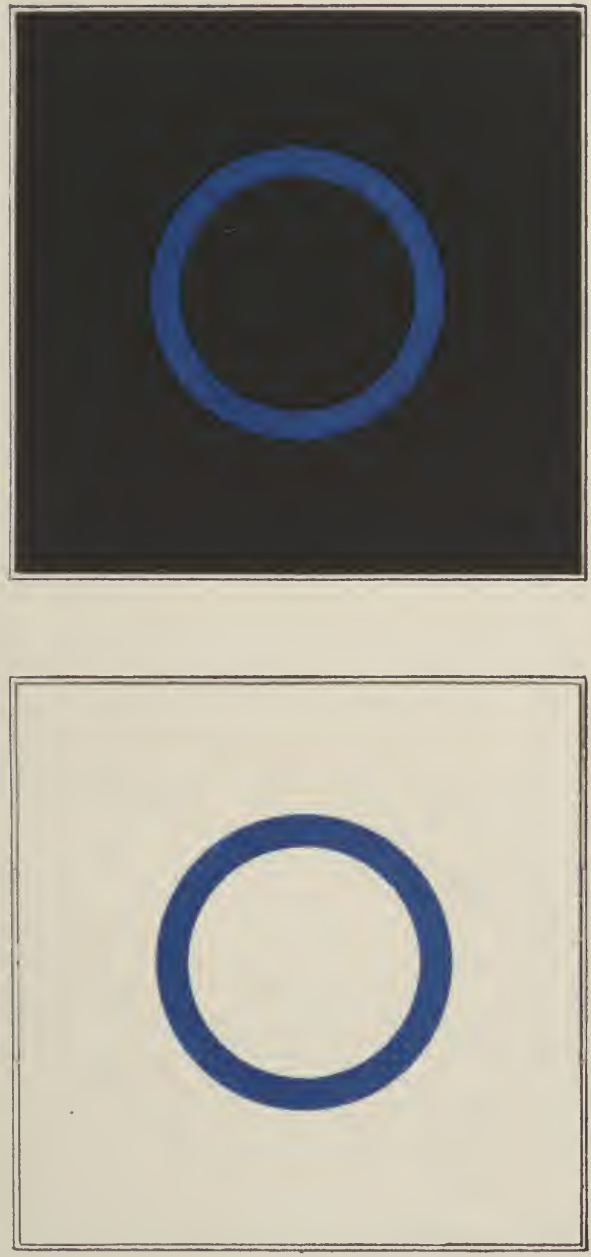


Illustration of the Effect of Surrounding Field on the Test Object for Blue.

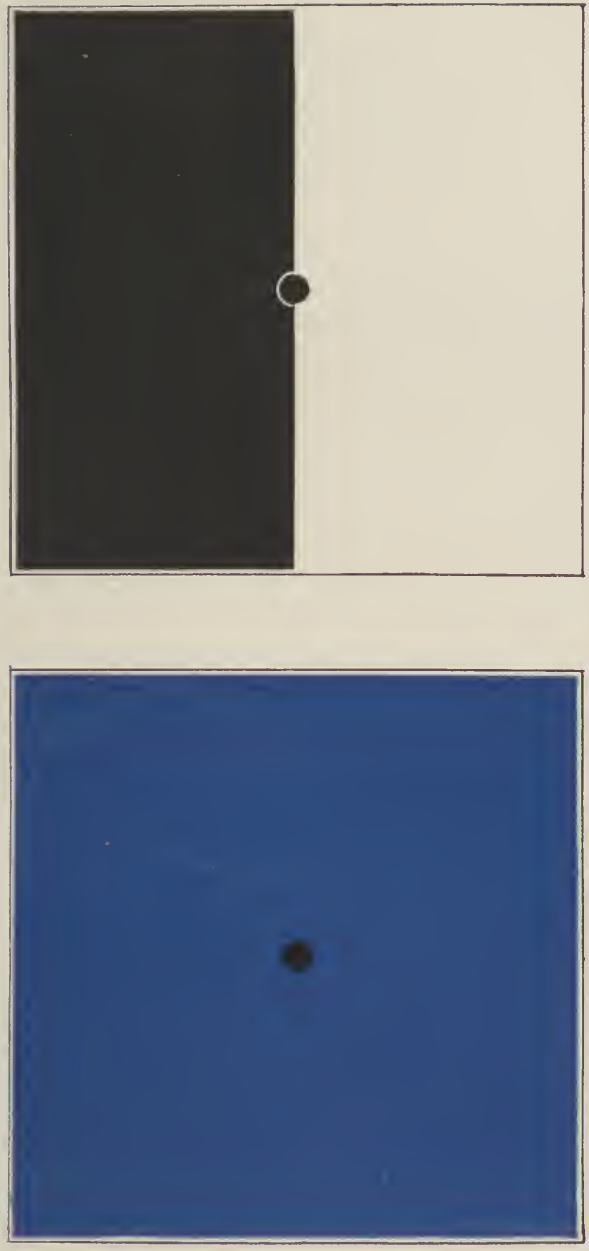
operator should be constant and uniform. To make the work more accurate and scientific, on the Ferree-Rand perimeter, the source of light moves with the perimetric arm so that the band of light which falls upon the field under investigation is always constant. In addition the candle power is controlled by a rheostat. For a small flat surface, such as the hand campimeter or the Lloyd slate, an even diffusion of light is obtained by means of a single reflector. On large Bjerrum screens two or more sources of light may be thrown upon the screen to produce satisfactory results. While the illumination thus obtained may vary some in the several parts of the tangent surface, for practical clinical work the results will be satisfactory.

Surrounding Field.—Writers on the subject of perimetry have called attention to the effect of environment and surrounding field upon the results of field taking. Some have suggested that a black or gray screen be placed in front of the patient, that the instrument be painted in black or gray and that the operator should wear a black or gray gown and even wear black gloves. These suggestions, for the most part, are intended to avoid the interference which conspicuous objects might have upon the patient which might prevent his proper concentration upon the work in hand and influence his answers. While this has some bearing upon field taking, the real reason for proper precautions is the effect which surrounding field has upon the color of the stimuli. If one carefully compares the blue ring in Plate III, *A*, with the one in Plate III, *B*, it will be noted at once that they are not of the same hue. The blue surrounded by white seems to be darker than the blue surrounded by black, although as a matter of fact the blues are exactly the same shade. The difference in the shades of blue becomes more pronounced as the illumination is diminished and the experiment is conducted at increasing distances from the eye. While the variations due to surrounding field are not so marked as those caused

by differences in the degree of illumination, they have a distinct bearing upon the extent of the field. It is necessary, therefore, that the surrounding field should be a gray of the same brightness as that of the colored stimulus employed. The gray will naturally be different with each colored stimulus used. On the Ferree-Rand perimeter this phase of the work is carefully provided for. By a proper modification the same principle can be incorporated in tangent field studies. If only form fields are being measured, the white test object is exposed on a black background.

Preëxposure.—By preëxposure is meant the stimulation of the retina under investigation by a gray of the brightness of the colored stimulus. In Plate IV this is graphically illustrated. The reader is asked to gaze intently for twenty seconds at the center of Plate IV, *A;* the gaze is now directed to the center of the chart in Plate IV, *B*. He will note that the blue chart is divided vertically, the left half being of a darker shade of blue than the right half. The former was preëxposed to white and the latter to black. When the experiment is conducted on a larger scale the contrast is more pronounced. This factor has an important bearing upon field taking and the results obtained. In order to obtain true and uniform results, a proper preëxposure of the retina to a gray of the brightness of the colored stimulus employed is necessary. To the casual observer these differences may not seem to be of sufficient moment to have an appreciable effect upon field studies. The experiments, conducted by Ferree and Rand, to whose original papers the reader is referred, have shown so great a variation that the careful student in perimetry cannot fail to take the matter into serious consideration. This is particularly true in the detection of slight peripheral field changes, upon which may rest the diagnosis or at least a localizing symptom which may lead to a correct diagnosis especially in obscure brain lesions.

PLATE IV



A Demonstration of the Effect of Preëxposure Upon Blue.

Intensity of the Stimulus.—The intensity of the stimulus depends upon the illumination, the size of the stimulus, the hue of the color employed, and the distance of the stimulus from the patient's eye. The quantitative method of perimetry, practised by Bjerrum and more recently advocated by Sinclair, Walker and others, is based on the variations in the size of the test object. A large white test object will be seen further in the periphery than a small test object. The intensity in this instance is varied by the size of the test object and also by the illumination. It furnishes concrete evidence that the form field may be varied in breadth by increasing or diminishing the size of the test object. Normal color fields are more sensative to such changes than the form field. In pathology of the visual pathway sensitivity or insensitivity to varying degrees of intensity of the stimuli are greatly increased, and the same may be said of the hues of the pigments employed. For example, a dark shade of blue will not outline the same limit of the blue field as a light shade of blue. It is now definitely known that if the intensity of the red and blue stimuli is properly increased, these colors may be recognized as far in the periphery as a white stimulus. Green, however, falls far short of the red and blue limits even if the highest intensity is used.

Not only illumination, the size of the test object or angle subtended by the test object, and the distance of the eye from the test object must be taken into consideration, but the character of the colored pigments as well must receive due attention. To this end the Heidelberg papers are recommended as standard colors and the modern correct instrument is equipped with these papers. The Herring pigments are also largely employed. The former are through-and-through and do not present a white edge when cut and have an additional advantage of not fading.

Fixation.—A factor which is often directly responsible for the so-called interlacing of the color fields is

fixation. Little attention has been paid to this phase of perimetry. In laboratory work where accuracy is an absolute essential, the wax bite is employed. The patient, when in proper position, bites into wax which hardens and at all times the patient's head may be brought into proper alignment by means of this device. Other aids for clinical work have been proposed. A mirror is placed in the center of the instrument in some instances to aid the patient in holding a correct position, as he must see his own eye in order to fix properly. In Bjerrum types of screens, and on the Ferree-Rand perimeter, a second point or ring is placed between the patient's eye and the point of fixation. This is a practical device. In others a peep sight is placed back of the instrument so that the operator may check up on the patient from time to time. If none of these devices is employed it is important that the operator should watch constantly to see that the patient's position is correct.

On the Ferree-Rand perimeter, Elliot's scotometer and on other instruments, a chin and head rest are provided. This latter method serves the purpose well, and tends to insure most accurate results.

Quantitative and Qualitative Perimetry.—It is a well known fact that the size of the test object has a distinct effect upon the size of the field even for form. This is one method of increasing or of diminishing the intensity of the stimulus to which the reader's attention has been called. If the peripheral limits of the field show no irregularity by the ordinary stimulus, those who advocate this method recommend a gradual reduction in the size of the test object in order to demonstrate the presence of minute changes. To this type of field study the term quantitative perimetry is applied. All who practice perimetry extensively employ the method in suitable cases. Sinclair, Walker and Traquair especially have emphasized its value in detecting slight peripheral changes in brain lesions. The special advantage of the method lies in its simplicity. A

black tangent screen or perimeter and white test objects of varying but definite sizes suffice and preëxposure and surrounding field need not enter so much into consideration. It is a method which should be taken at its face value with full knowledge of its limitations and the only too great tendency to which it leads, namely encouraging indifference to the more exact and correct qualitative method of determining the sensitivity of the retina to colors as well as to form. For sharply outlining the dividing line in lateral hemianopsia, it serves a useful purpose, and in comparative studies, from day to day, in progressive or regressive intracerebral conditions, involving the chiasm or the visual pathway posterior to the chiasm, it saves time and furnishes valuable information. It does not tell the whole story and as it is not as sensitive as colored stimuli subtending the proper angle, it should not be employed to the exclusion of the qualitative method. The author has frequently called attention to the fact that loss of sensitivity for blue is apt to precede changes in red and green in nutritional disturbances affecting the neuro-epithelial layer of the retina; and similarly that green and red shrinkage precede that for blue in disease of the nerve fibers or the transmitting part of the neuron. These changes have been observed before any change is recognized in the white field. Failure of the proper saturation of green for example is the earliest evidence of a beginning Bjerrum sign in glaucoma, whether the scotoma begins as an enlargement of the blind spot of Mariotte or as a detached area above or below the point of fixation.

It is the author's firm conviction, therefore, that the beginner should first master the intricacies of a proper qualitative technic and employ it routinely in field taking and should apply the quantitative method to the conditions for which it is especially adapted, *i.e.*, for determining the dividing line in hemianopsia and for comparative study, especially of neurological cases, when measurements must be made frequently

and time and the fatigue of the patient must be considered. It is not the author's purpose to minimize the value of any method of study which will aid in diagnosis, but rather to give each method its real value and place in field technic. It is his conviction, however, that a protest should be made against any effort to replace qualitative perimetry by a purely and exclusive quantitative method of study.

Test Objects or Stimuli.—Although several of the instruments now employed have a special technic peculiar to the instrument which will be discussed when the instrument is described, there are general principles which are common to all. For practical clinical purposes the same general character of the test object applies to all instruments. The stimulus should be so constructed that nothing but the test object is exposed to the patient's eye. Flat discs of the proper size should be attached to long slender rods, painted black or a neutral gray as the case may demand. When the studies are made on a black surface with a white test object, the rod should be black and when a gray surrounding field is employed the rods should be in neutral gray. The best type of disc is that devised by Dr. Clifford Walker of Springfield, Mass., known as the knife-edge disc.

These discs are slightly countersunk to protect the paper pigments, the edge of the carrier being so narrow as to be likened to a knife edge. The colored paper practically covers the entire surface of the disc. Care should be observed, if the metal is brass, that it does not become worn or shiny, as this will render the test object unsuitable for careful work. The stimuli found on the ordinary perimeters are practically useless as they are placed on a carriage, on the arm of the perimeter, which is so conspicuous that the patient looks rather for the moving of the carriage than for the inconspicuous test object. Furthermore, the stimulus, as a rule, is so deeply countersunk that the patient can see it with great difficulty. For this reason self-registering

perimeters lose much of their value. When a perimeter other than a Ferree-Rand, or a perimeter constructed on the same standard basis, is employed, a hand test object such as the one described will be found most satisfactory.

Size of the Test Object.—In recent years much attention has been paid to the size of the test object and the manner of expressing the same. It is a time-honored custom to express the size in millimeters in diameter. If this method is used, one must know the length of the radius of the instrument which was used in order to know definitely the angle subtended. While it is desirable in many instances to know the distance of the eye from the point of fixation, it is not always necessary for the average case unless accuracy of the field is in question. To simplify and make all methods uniform it therefore is desirable to express the size of the disc in the size of the angle which the disc subtends, expressed in degrees, minutes or seconds. Some of the instruments now used have stimuli so expressed and it is to be hoped that the method will become uniform and a standard in perimetry.[1]

For those who wish to use the old form of designating the test object, it will be necessary to give in figures, the diameter of the test object in millimeters and also the length of the radius. 3 mm.—1000 mm. would indicate, for example, that the stimulus was 3 mm. in diameter and the study was made on an instrument of 1000 mm. radius. Sometimes this is incorrectly written 3/1000. This is a short method but one which is misleading, as the fraction expresses really nothing as a fraction. If the newer and more correct method is used, a similar formula may express the data. For example, 1 degree—1000 mm. would indicate that the test object subtends an angle of 1 degree and the radius of the instrument is 1000 mm.

The size of the test object most desirable for routine

[1] See resolutions offered by the author in Trans. of An International Congress of Ophthalmology, 1922.

clinical use is *sub judice*. For the Bjerrum type of screen an object as small as 1 mm. is employed by some. Others feel that this test is too small and may err in using a stimulus too generous in size to do accurate work. Both extremes will fail to bring out the greatest refinements in perimetry. The visual angle, upon which are based and constructed the charts used in determining central visual acuity, is 5 minutes, wth a minimum of 59 seconds. Gradle[1] quotes Sulzer's figures in the rapid falling off of sensitivity from the center of the macula to the peripheral border of the blind spot of Mariotte, as follows: At the inner border of the blind spot, the visual acuity is only $\frac{1}{22}$ that of central acuity; at the outer border of the blind spot, it is less than $\frac{1}{55}$ of central vision. With this fact established by others as well as by Sulzer, it is evident that too small a stimulus will lead to uncertainty and to error. For practical routine work the stimulus should be 30′ for study up to and including the blind spot. For peripheral field work a 1 or 2 degree test object should be the routine size. When central vision is much reduced, a larger test object may be necessary. When a white object is used for outlining small scotomata centrally located, or when the purely quantitative type of peripheral field studies is made, a much smaller stimulus may serve the operator best. These, however, are the exceptions. Routine studies may need amplification by a modification of the rule but the student in perimetry will do well to continue his work on an average basis until his experience warrants marked digression.

Colored Stimuli.—One has the choice of using either colored papers or mixed pigments for the colored stimuli. As the latter are uncertain and not reproducible, colored papers alone are now employed. Two papers are offered as sufficiently standardized to admit of adoption—namely the Heidelberg and Herring papers.

[1] The Blind Spot, Second Communication, Annals of Ophth., October, 1916.

The former are through-and-through, do not fade, have no white cut edges to show, and seem to have the proper hues for clinical work. The Herring papers are not through-and-through, show a white edge, and by some are said to fade. The Heidelberg paper has been adopted by many instrument makers and if universally accepted, would contribute an important link in making the technic of perimetry uniform. Colored glass stimuli on certain perimeters, illuminated by transmitted light, are objectionable because of inability to obtain uniform mixed pigments.

Method of Exposing Stimuli.—In peripheral studies the test object is always passed from the periphery toward the center of fixation, or from beyond the visual limits until sensitive retina is reached. If one passes the stimulus in the opposite direction, a larger and incorrect field will be obtained. In studies of the blind spot of Mariotte and of central pathological scotomata the same rule should be followed. The stimulus should be passed from blind to sensitive retina. This insures accuracy. Inasmuch as small stimuli are used, it is always well to pass back and forth until the exact dividing line is reached before a permanent record is made of any part of the scotoma. The precaution is particularly important in outlining the outer limits of Mariotte's blind spot.

Movement of Stimuli.—When peripheral fields are cut to a considerable degree and the entire retina is more or less irresponsive to stimulation, it is helpful and correct to impart a vibratory motion to the stimulus to determine the peripheral limits. Spiller and others have called attention to this function of the peripheral retina—the ability to recognize moving objects better than those at rest. According to these writers it is a primitive function—the last to go and the first to return. One can save much time by first developing the so-called movable limits, and after this is obtained, by developing the peripheral limits sensitive to stimuli brought to rest. In all studies,

aside from the movements imparted to the stimulus as just described, the test object should be moved slowly and at sufficient intervals so as not to miss any defect either in the peripheral field or in the central area.

Number of Points to be Studied.—There is no hard and fast rule to follow in developing either peripheral limits or central defects. The usual method of many investigators is to routinely make eight points of study in outlining the peripheral field. The cardinal directions and four points midway between them are usually selected for investigation. This is totally insufficient. One is more apt to fall into this error when working on a perimeter than on a campimeter. On a tangent plane the test object is so flexible in its movements that one naturally follows an angular defect automatically. There should be no fixed rule other than that of care. The peripheral field as well as a central defect should be studied at intervals sufficiently close to preclude the possibility of error or oversight. Experience in the work alone can give the operator the necessary knowledge as to when it is safe to make studies at wide intervals on the arc. Thoroughness always brings good returns and indifference is paid in its own values.

Glasses in Presbyopia and in Defective Vision.—Objections have been raised to the use of instruments of short radii in presbyopia and in high hypermetropia. In central field studies this is easily overcome by allowing the patient to wear the correction to which he is accustomed. In peripheral work this rather complicates the examination, because an ordinary glass does not admit of extreme peripheral vision to record the true limits of sensitivity of the patient. In high myopia, on the other hand, studies at a distance of a meter are equally embarrassing, especially, because very high errors are encountered. The difficulty, however, is not so great as it might seem to be. The rapid falling off of sensitivity of the peripheral retina has been referred to. When one estimates the loss

in central vision in high hypermetropia and in presbyopia, the reduction does not have so great an effect on peripheral vision as to interfere materially in doing fairly accurate work. In hypermetropia and in presbyopia, the intensity of the stimulus can be increased by increasing the angle which the stimulus subtends. In myopia instruments of short radii may be selected, and if necessary, the stimulus can be increased in size. When practicable, however, a suitable correction of the refractive error should be worn.

INSTRUMENTS.

It will be impossible to do justice, or even to mention, all the perimeters and campimeters which have been used to advantage. Our purpose will be served best if only those which seem to be of great value are presented. Many of undoubted value can not be included. It is our purpose to omit none if they contribute anything of value which cannot be cared for equally well by one of standard make.

PERIMETERS.—The Ferree-Rand perimeter is so superior to any instrument which has thus far been offered that older models naturally fail to elicit any enthusiasm in their presentation. In fact the incompleteness of the old models in fundamental essentials is largely responsible for the popularizing of studies on tangent planes.

In Figs. 17 and 18 is represented a model of the Ferree-Rand perimeter. It is impossible in a photograph to illustrate all the advantages of the instrument. Fundamentally it does not differ from the original Förster model. It is not automatic in recording nor is it, in the truest sense, a hand instrument. The illumination is correct and uniform in all meridians as the illuminating arm moves with the perimetric arc and sheds a uniform band of light along the entire surface of the arm. The frame is painted in a neutral gray. The chin and head rest insures accurate fixation. A two

point fixation requires perfect alignment and correct position of the patient's head. The radial length is 33 cm. The stimulus is placed in the center of a cardboard about 15 cm. square, covered by a gray of the brightness of the stimulus. When studies are made, the test object is covered by a second cardboard of the same gray.

FIG. 17

The first cardboard insures proper surrounding field and the second one a proper preëxposure. To facilitate matters, the approximate peripheral limit is obtained by slowly moving the test object in along the arm of the perimeter until it is recognized. The correct limit is then obtained by preëxposing and uncovering the test object moving it back and forth until the

most peripheral point is obtained where the stimulus is distinctly seen in its proper color. Form limits are obtained in the same manner, with the white test object on a black card.

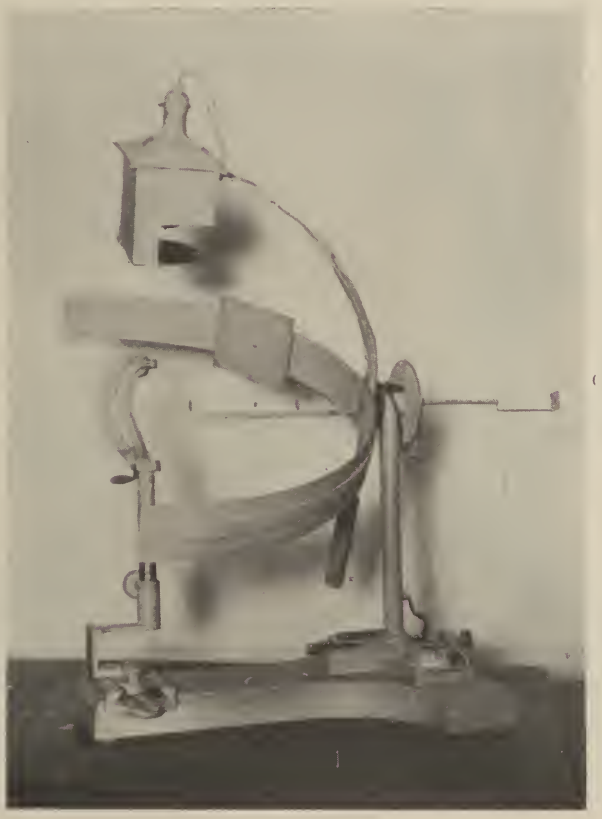


FIG. 18

FIGS. 17 and 18.—Ferree-Rand perimeter with attachments for illumination, fixation, tangent screen, preëxposure, and surrounding field.

The perimeter is equipped with a small tangential screen for studies of the central area. A second attachment of unusual merit is a four-point fixation device for use when central vision is affected by a central scotoma. A peep sight, which is operated by the physician from behind the perimeter, determines when

the eye is properly centered and the four points for fixation are approached to the edge of the scotoma. The examination proceeds with this fixing device as previously described. The instrument has been described with considerable detail because it differs radically in operation from any form of perimeter now available.

FIG. 19.—McHardy's self-registering perimeter.

In physiological studies, Drs. Ferree and Rand have obtained results practically equal to those obtained by the most accurate laboratory technic. It requires more time than work on an ordinary perimeter, but the results, in detecting minute peripheral changes, more than compensate for the time required.

The ordinary type of perimeter is illustrated in Figs. 19 and 20. These are equipped with automatic recording devices which save time but fail to yield

accurate results. Illumination is imperfect. The test objects are unsatisfactory, whether mounted on the ordinary carriage or consist of colored-glass discs, through which light is transmitted by electric bulbs. No provision is made for preëxposure and surrounding field. The test objects lack delicacy. The large moving carriage rather than the test object, attracts the patient's attention, All these are important factors in detecting slight contractions, especially in brain lesions when a diagnosis may rest entirely on

FIG. 20.—Universal perimeter.

slight unilateral or hemianopic field defects. This type of perimeter fails in the part of the field in which a properly standardized perimeter should be of most use. Defective illumination can be corrected by a lantern similar to the one used on the Ferree-Rand perimeter, but at best it cannot be made satisfactory for the work for which it should be well adapted, unless it undergoes radical change in its construction.

Schweigger Hand Perimeter.—A hand perimeter as devised by Schweigger is illustrated in Fig. 21. It is

adapted to bedside work and for home use in approximately determining peripheral limits of the field under trying or emergency conditions. The radius is 16½ cm. or ⅙ of a meter—one-half the radial length of the average perimeter.

FIG. 21.—Schweigger's perimeter.

Umbrella Perimeters.—Perimeters of unusual design have appeared from time to time; notable is the umbrella perimeter constructed by Reber and McCool and one of a similar design, but on a larger scale, used by Clifford Walker. The difficulty of illumination and mechanical difficulties from an operating standpoint, in addition to their bulk, detract from their popularity for office use.

One-meter Perimeter.—A number of perimeters calculated to be operated at a one-meter radius have been in use to a limited extent. They are similar in construction to the one represented in Fig. 22, an instrument used by Lt.Col. R. H. Elliot.[1] Like the umbrella type, these large models require too much space in which to operate, to make them popular or even of value.

Basket Perimeter of Morton.—This ingenious device is intended for rapid work. It has, however, nothing to commend it and has so many objectionable features when contrasted with the hand perimeter of Schweigger, that it cannot be regarded as an instrument of value.

Chord Perimeter.—Dr. S. Holth of Christiana has perfected a pocket perimeter, especially adapted for quick work and so compact in construction that it may be carried in the pocket. The arc of the perimeter is replaced by two straight wooden rods, representing the chords of the two quadrants which would make up the arc. The test object is passed along the chords. The author claims results of a fair degree of accuracy.

Campimeters or Tangent Screens.—Von Graefe was the first to recognize the advantages of study of central field defects on a flat surface. In recent years the popularity of this method of study was increased by the Bjerrum type of screen and by so many useful modifications, that it is now regarded as the method of choice for studies within a radius of thirty degrees from the fixation point. Three types of screens, with numerous modifications, are now in use: (*a*) The Bjerrum screen which is operated at a radial length of one to two meters; (*b*) tangent screens of short radial length; and (*c*) a tangent plane in which the entire tangent is rotated. The first type is designed especially for minute analysis of scotomata centrally or paracentrally located; the second group are adapted to rather rapid routine studies of peripheral limits and of blind areas within

[1] A Treatise on Glaucoma, 2d Ed., p. 264.

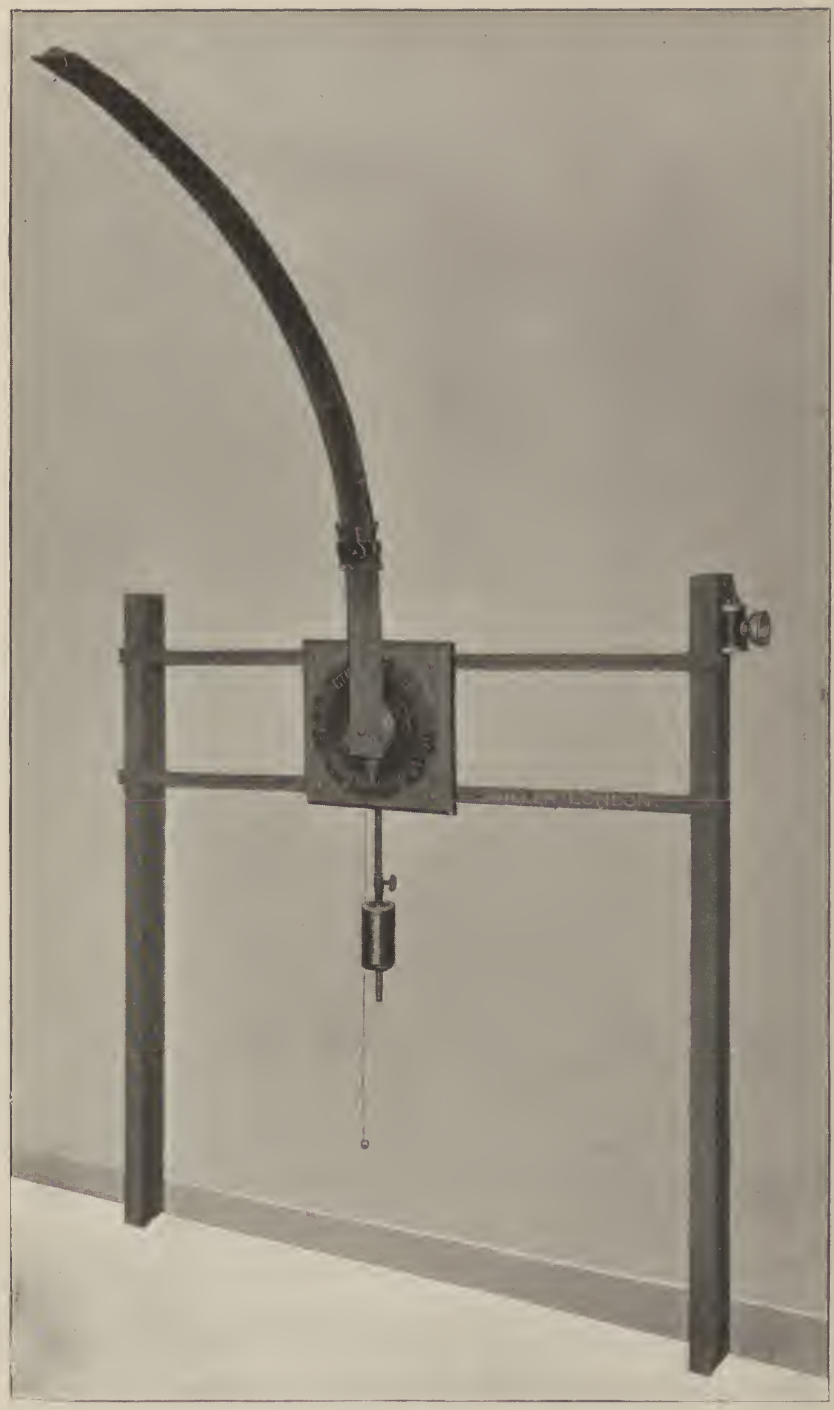


FIG. 22.—Col. Elliot's large one-meter perimeter.

thirty degrees of the fixation point; the third type is essentially of the Bjerrum form of plane with the advantages gained by imparting a circumferential motion to the test object.

Bjerrum Screen.—In 1889 Bjerrum[1] offered to the profession a method of analyzing scotomata which has received much attention. He employed a flat surface of black cloth supported and stretched over a framework, with the patient seated at two meters from the screen. Instead of the usual-sized test object ordinarily employed for peripheral field studies, the test object consisted of an ivory white ball attached to a slender black rod, the test object being 1 mm. in diameter. According to Sinclair[2] peripheral limits of a 1 mm. white test object at 2 meters distance from the screen, are to the temporal side 26 degrees, to nasal side 26 degrees, up 24 degrees, and down 25 degrees—a marked reduction of the true limits obtainable by a stimulus of greater intensity. The advantage, however, of this method lies in the fact that small defects are relatively increased in size when studied at a great distance from the tangent surface, and in the insensitive areas the test serves as a means of detecting early loss when large stimuli would fail to reveal such a defect. Too great a reduction of the intensity of the stimulus may also lead to error. For example, those who have had considerable experience in perimetry can testify to the difficulty of outlining correctly the outer limits of the normal blind spot of Mariotte by minute stimuli, as contrasted with the determining of the inner border. This is due to the falling off of retinal sensitivity from macula to the periphery. While the outer edge is but 5 or 6 degrees further removed from the macula than the inner edge, a stimulus of sufficient size should be used to admit of no uncertainty as to when it is visible and when it disappears. In the judgment of many advo-

[1] Nordisk Ophthal. Tidskrift, 2, p. 3.

[2] Tr. Ophth. Soc. United Kingdom, 1905, p. 38.

cates of this method, therefore, a modification of the same will serve the purpose best. Working at a radius of 1 meter instead of 2 meters, with a test object which subtends an angle of 5 to 30 minutes

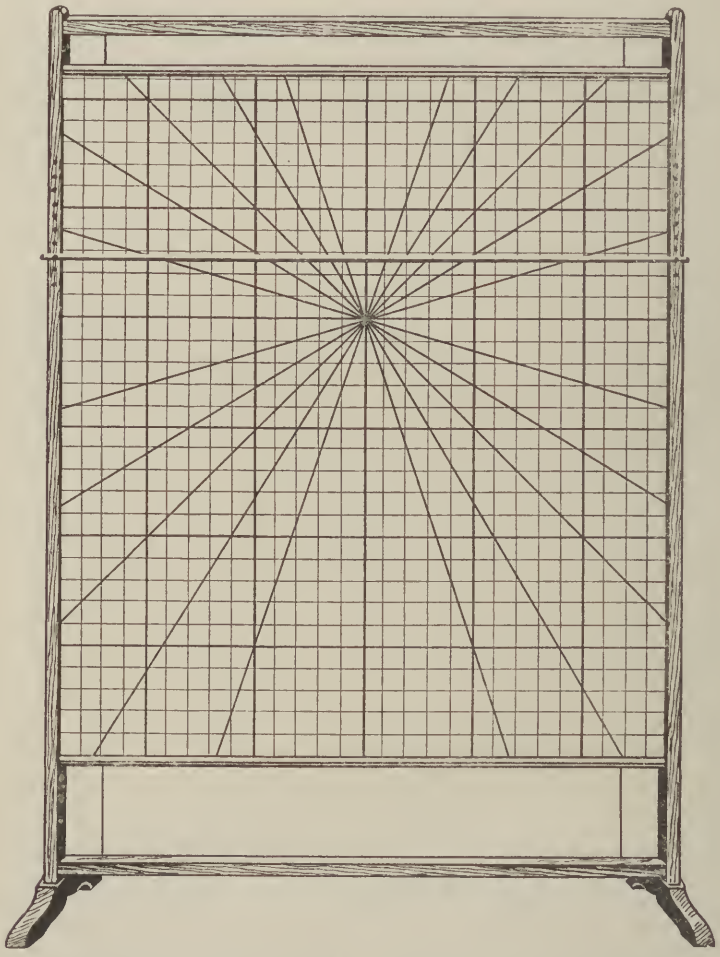


FIG. 23.—Tangent curtain of Duane. (Courtesy of G. P. Putnam's Sons.)

as the case may demand, will avoid the errors and will lose nothing in accuracy or efficiency.

Sym and Sinclair[1] used a similar screen covered by

[1] Ophthalmic Review, 1906, 25, 141.

heavy black velvet. Duane's screen, Fig. 23 is a modification of the same type of screen. The author prefers a blackboard as shown in Fig. 24, which is correctly illuminated by artificial "daylite" filters. There is an advantage in a firm surface in the form of a blackboard which may be painted on the office wall or may

Fig. 24.—The author's model of a one-meter tangent screen equipped with "daylite" filter illumination, and adjustable table, chin and head rest.

be an independent unit as in Fig. 24. Gradle[1] advocates a blackboard of a 50 cm. radius for practical purposes. In October 1916[2] the same author described his tangent screen in which the test object is moved about by means of a magnet operated from behind the screen.

[1] Nebraska State Med. Jour., March, 1922.
[2] Annals of Ophth.

E. Marks, in 1920, apparently without knowledge of Gradle's instrument, presented a tangent screen with the test object operated in the same manner. In all these campimeters, the tendency is to shorten the working radius to 1 meter or less, while the stimuli are somewhat larger than those originally used by Bjerrum.

Tangent Planes of Short Radius.—The second group of campimeters serve a slightly different purpose than those just described. They are campimeters of short radius, and are intended for rapid routine work rather than for minute analysis. They enable the operator to outline defects of the central field at a minimum loss of time and with sufficient accuracy to be dependable for average clinical cases.

The first of these instruments to be offered to the profession was the hand campimeter of the author, presented before the American Academy of Ophthalmology and Oto-Laryngology, in 1915. (See transactions for that year.) Like the Schweigger perimeter, which was designed for rapid peripheral field work, the campimeter was designed for rapid central field studies. In actual practice, however, it proved to be well adapted for the measuring of pathological peripheral field contractions when such contractions fell within 40 degrees of the center of fixation. The special advantages of the instrument are: (1) It enables one to pick up defects in the central field and in the periphery within 40 degrees of the fixation point, in much less time than by any other method with which the author is familiar; (2) it admits of good illumination by a single reflector of artificial daylight; (3) it has charted on its surface average normal blind spots so that enlargements or displacements of the normal blind spot can readily be detected; (4) it probably is the most inexpensive instrument on the market. Dr. Redding, of Scranton, Pa., attaches the campimeter to the arm of his phorometer. This, he claims, admits of accurate adjustment, and renders the examination less tiresome to the patient and insures greater accuracy.

Since 1915 this instrument has been used routinely by the author, not to the exclusion of the perimeter and other types of tangent planes, but for preliminary study, the other instruments being held in reserve for the analysis of the particular defect which the campimeter clearly points out needs more careful analysis

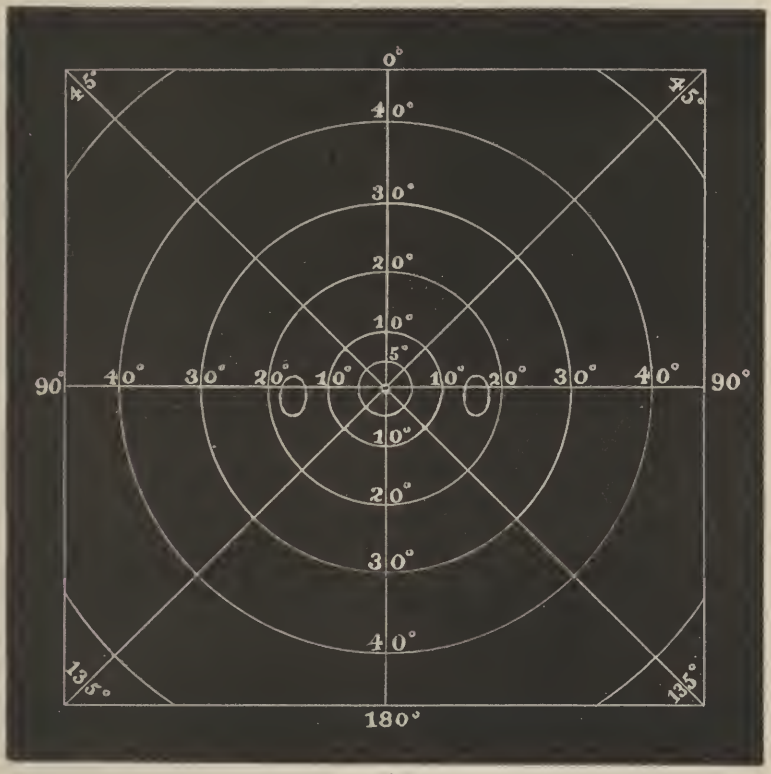


FIG. 25.—Author's hand campimeter.

and amplification. If the reader will use the instrument in the same manner, he will take more fields, uncover many defects which are unsuspected, and will realize that the time consumed is profitable. Having discovered a field defect which throws light upon otherwise obscure cases, one needs no further inspiration to spend much time in analyzing a symptom or

sign of great value. Like all instruments it has its limitations which must be observed and respected. It has a breadth of application, however, which those who have not used it correctly cannot fully appreciate.

A campimeter, similar in construction and in operation to the one just described, is the scotometer of N. Bishop Harman[1] of London, presented before the

FIG. 26.—Author's hand campimeter in use.

Section of Ophthalmology, Roy. Soc. Med., January 14th, 1921. It has the advantage of a longer radius, 33 cm., although laterally its limits are 26 degrees and vertically, 17 degrees. It, therefore, is purely a scotometer in which respect it is similar to the Lloyd slate. The two features which especially commend it are the outlined blind spots of Mariotte, and the method of

[1] British Jour. of Ophth., April, 1921.

recording directly. The claims of the designer for rapidity and accuracy seem to be entirely justified.

A recording scotometer devised by E. O. Marks[1] of Brisbane, Australia, is unique but probably not so refined in its technic as the one just described.

The Lloyd Stereo-campimetric Slate.—In 1904, Haitz introduced stereoscopic charts for the detection of central defects, the charts being adjustable for use with the ordinary stereoscope. Although extremely limited in application, the method opened the way to the adoption of binocular and stereoscopic fixation on a broader scale. Bissell, of Rochester, improved on the Haitz charts by enlarging the field of study to include the blind spot of Mariotte. It remained, however, to Lloyd,[2] of Brooklyn, to give to the profession a stereoscopic scotometer of real value and of considerable range. To quote the author, "It is especially adapted for work in the central and paracentral areas, blind spots and fixation areas. As each field may be examined independently of the other but with binocular fixation, steadiness and accuracy are evident. If one fixation area is affected, the good eye will fix and hold the one not able to fix by itself." The slate includes an area of 35 degrees to the temporal side, 10 degrees nasally and 25 degrees above and below the fixation point.

The author has found this instrument to be one of the most important additions to his office equipment and can testify to its value in central studies.

Rotating Campimeters.—The third group of tangent planes have the specific feature of a rotating disc so that the stimulus is moved in a circumferential manner around the point of fixation.

One of the first of this type of scotometers was that of Priestley Smith, which consisted of a black disc, 39 cm. in diameter, operated at a radius of 35 cm. The Bardsley scotometer is a sector of a hollow sphere, the test object being moved from behind by the operator's

[1] British Jour. of Ophth., April, 1921.

[2] New York Med. Jour., December, 1920.

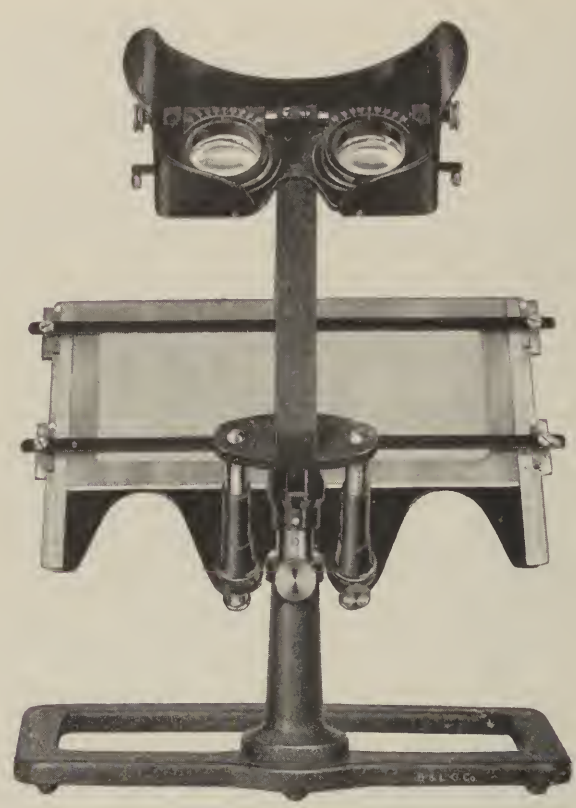


FIG. 27.—Lloyd's Stereo-campimetric Slate.

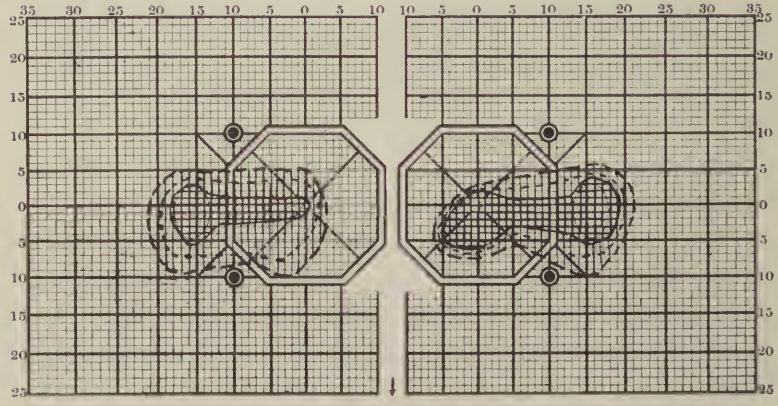


FIG. 28.—Chart used on the Lloyd Slate.

hand, invisible to the patient. Its operation is similar to the perimeter although resembling more the disc of Priestley Smith in that the entire sector rotates. An added advantage is the opening in the center of the disc, through which the patient's eye may be watched and better fixation secured.

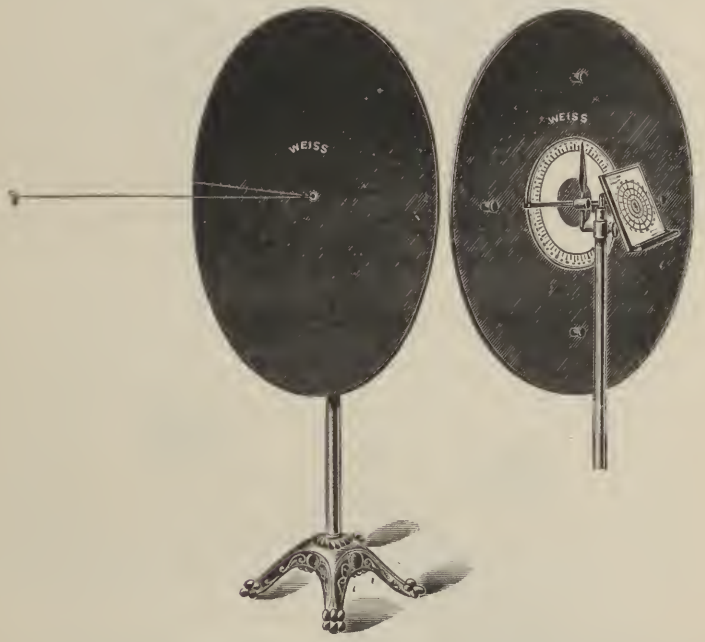


FIG. 29.—Elliot scotometer and recording chart. (Courtesy of Henry Frowde and Hodder and Stoughton.)

The scotometer of Lt.-Col. R. H. Elliot[1] is the instrument in this group which has received more attention than the two just mentioned and others of a similar character. It probably received its inspiration from the Priestley Smith scotometer, and has much in common with that instrument. It is operated at a radius of one meter, and in addition, a chin and head rest secures good fixation. In operation, a small white disc or bead is attached to a black cord which runs

[1] A Treatise on Glaucoma, 2d Ed., p. 257.

from center to periphery, which is 26 degrees from the center. As the disc is rotated, the points at which the test object is lost, found, etc., are noted by an assistant behind the screen, recorded on a suitable chart Fig. 29, computed and transferred to a special chart Fig. 30. Types of blind spots and field defects obtained by the instrument are recorded in Figs. 31 and 32.

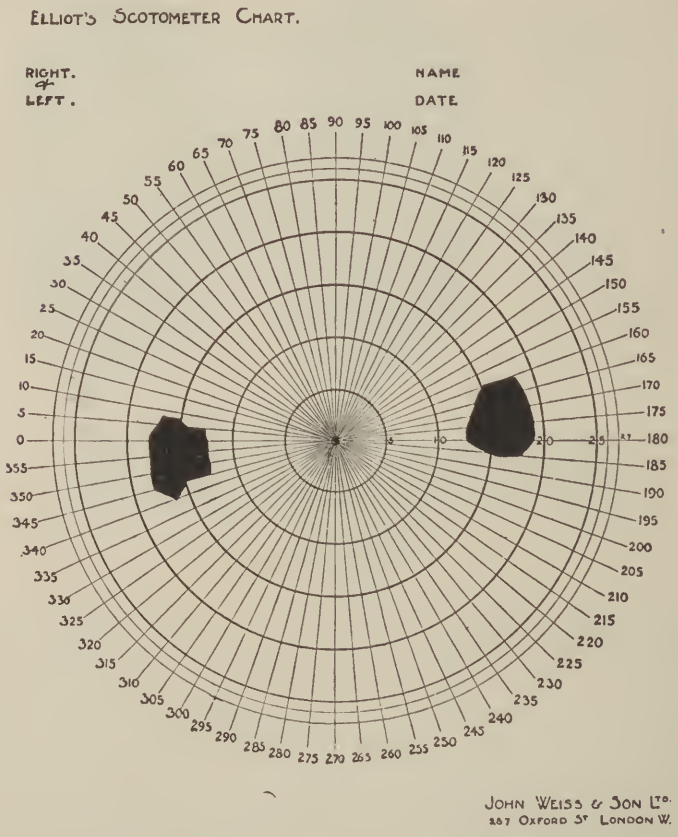


FIG. 30.—Elliot record chart. (Courtesy of Henry Frowde and Hodder and Stoughton.)

The special advantage claimed by the designer of the instrument is the operation or movement of the test object in a circumferential direction or along the line of the development of the Bjerrum scotoma found in glaucoma. Those who have used the instrument,

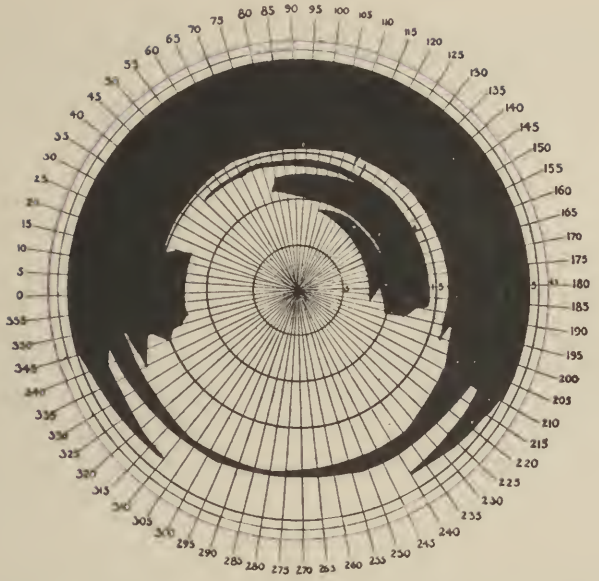


FIG. 31.—Juvenile glaucoma. (Elliot.) (Courtesy of Henry Frowde and Hodder and Stoughton.)

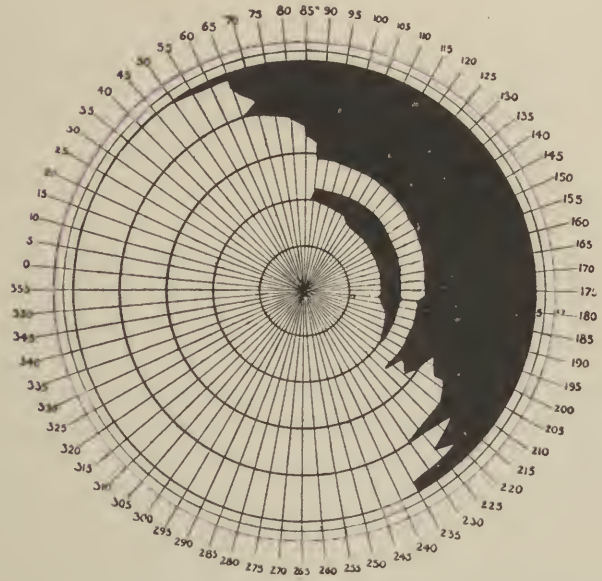


FIG. 32.—Chronic glaucoma. (Elliot.) (Courtesy of Henry Frowde and Hodder and Stoughton.)

substantiate the claims of Col. Elliot that the blind spot in this disease, elicited by the Elliot scotometer, has a peculiar jagged margin, which is not obtained by any other instrument or method of study—the so-called Elliot sign.

In selecting tangent screens for office use it should be clearly borne in mind that a perimeter is not adapted to central study because of the inelasticity of mechanically operated instruments. One is obliged to work in fixed channels.

The advantage of the tangent plane, on the other hand, lies in its great flexibility—the ability to operate the stimulus by hand in not only a radial or a circumferential direction but in any direction found necessary to properly outline the defect. While each of the tangent planes possesses merit, preference should be given to those which admit of freedom of motion to the stimulus and do not require its movement in a set channel. There is force, however, in Col. Elliot's contention that his scotometer operates in a direction which is apt to pick up the central changes which may occur in glaucoma and many have found his instrument of much value in this disease.

Method of Constructing Tangent Planes.—The practicability of constructing a tangent plane for use in office or clinic, at little expense, is evident. For the benefit of those who may desire the information, the following instructions will be found adequate.

A firm surface in the form of a blackboard is generally more satisfactory than black cloth stretched over a frame. A flexible blackboard cloth, which may be rolled up and removed when not in use, or a child's blackboard, as shown in Fig. 24, may be adopted, or a blackboard may be painted on the wall of the office or clinic as suggested by Gradle. The best type of design to use on the board is that shown in Fig. 25, the design of the hand campimeter. In order to draw the circles and blind spots correctly, the length of the radius at which the operator chooses to work should be decided.

For most practical use, a 1-meter radius will be found to be the best, although any radius may be selected.

The following table of natural tangents may be consulted for the angles required:

NATURAL TANGENTS.

Tangent of 1′–.0003	Tangent of 5°–.0875
Tangent of 5′–.0015	Tangent of 6°–.1051
Tangent of 10′–.0029	Tangent of 7°–.1228
Tangent of 20′–.0058	Tangent of 8°–.1405
Tangent of 30′–.0087	Tangent of 9°–.1584
Tangent of 45′–.0131	Tangent of 10°–.1763
Tangent of 1°–.0175	Tangent of 20°–.3640
Tangent of 2°–.0349	Tangent of 30°–.5774
Tangent of 3°–.0524	Tangent of 40°–.8391
Tangent of 4°–.0699	

If the 30 degree circle is to be included, a board 4 feet square or round will be required. Vertical and horizontal lines, crossing in the center of the board, should be drawn in a faint gray, and oblique lines exactly bisecting each quadrant should be added. To find the radius of the 5, 10, 20 and 30 degree circles which should be outlined, one multiplies the natural tangent of these angles by 1000 mms. the radius of the instrument, and the result will be the radius of each circle in mms.

Tangent of 5 degrees, .0875 × 1000 = 87.5 mm.
Tangent of 10 degrees, .1763 × 1000 = 176.3 mm.
Tangent of 20 degrees, .3640 × 1000 = 364.0 mm.
Tangent of 30 degrees, .5774 × 1000 = 577.4 mm.

By means of a compass these circles may be drawn accurately and marked in gray as the other lines and dusted with charcoal to make them less conspicuous.

The blind spots are more difficult to place correctly. The average blind spot at a 1 meter radius measures 89 mm. horizontally and 122 mm. in the vertical diameter. The upper margin is 37 mm. above the horizontal line which passes through the point of fixation. From

the point of fixation to the inner edge of the blind spot on the horizontal line the distance is 232 mm., and to the outer edge the distance is 321 mm. With these points definitely fixed the ellipsoid may be outlined by free hand drawing and treated as the other lines. As the outline of each normal blind spot will vary some in shape and in location, it is a good plan to place the four extreme margins as directed, and to permanently chart the area after many examinations of normal individuals. The figures as given, however, will be found to be correct, as they are the average result of about 400 examinations and were subsequently confirmed by many other tests.

All these lines should be made as indistinct as possible so as to furnish a guide to the operator and not to be suggestive to the patient.

Illumination is important. Two long shed reflectors are placed on the sides of the board, each reflector containing two 125-candle power lamps or "daylite" units screened by frosted glass. Gradle uses three reflectors arranged in an arc over the patient. To make the equipment more complete and to lend accuracy to the test, it is well, when possible, to have the illumination accurately measured in foot-candle power.

For a chin rest one can use the device which Elliot uses with his scotometer. The author finds a table, which can be raised and lowered, more satisfactory. On the table a chin rest can be arranged and the patient's arms may be rested firmly and comfortably on the table.

The test objects to be used on this instrument are the following:

10 minute stimulus measuring 2.9 mm. in diameter.
30 minute stimulus measuring 8.7 mm. in diameter.
1 degree stimulus measuring 17.5 mm. in diameter.
2 degree stimulus measuring 34.9 mm. in diameter.

In exceptional cases a five minute test may be useful; this will measure 1.5 mm. in diameter.

Instruction to Patient.—Success in correct field taking depends largely on the intelligent coöperation of the patient. To this end, the patient should be carefully instructed, before an examination is begun, as to what the operator proposes to do and the part the patient is expected to play. It is well to explain the difference between central and peripheral vision. This difference can be illustrated in office or clinic by showing the patient how objects can be seen and recognized when not in line with central or macular vision. Instruction of this sort will save much time and annoyance after the work is begun. He should be instructed to give quick and accurate response at the moment the stimulus comes into the range of consciousness of the peripheral retina. When colors are employed, he should be told to call the color at the earliest moment when *full saturation* appears.[1] With a little practice the average patient, without much prompting, will volunteer the information of changes in the color. It is failure to have a distinct understanding in the matter of saturation that is responsible for some of the incorrect interlacings recorded—interlacings which are pure artefacts.

Practical Application of the Principles of Technic.—Field studies should not be made at the end of a prolonged ophthalmic examination, but at a specially appointed hour, when the patient is at his best and as free as possible from fatigue. A quiet room, free from annoyance and without an audience will be found conducive to good results. After he has been properly instructed, he should be comfortably seated at the perimetric table with arms and body free from constraint. Unless binocular fixation is employed, the eye

[1] Ferree, on the contrary, instructs the patient to note the first appearance of a greenish hue instead of full saturation when using a green stimulus, and the first evidence of red when the red stimulus is employed. This method explains the interlacing which he finds in taking the blue and red fields of a normal patient. The method, if practised in pathological studies, destroys the value of detecting early qualitative changes which are of great importance in optic-nerve disease, and especially in glaucoma.

not under investigation should be covered by an eye pad lined with fresh cotton. Care should be taken that the head is in proper position and so maintained, and that the eye is exactly the same height as the point of fixation. On the perimeter the form field should be studied first. The white test object, 1 or 2 degrees in size, is slowly moved from the extreme periphery toward the center until it is recognized. When seen by the patient it is again moved out toward the periphery a little. This movement of the stimulus is repeated until the operator feels confident that the most peripheral limit has been reached. The exact point should be noted on a chart and the next meridian should be studied in like manner. This method should be followed at reasonable intervals until the entire periphery has been properly studied and the results recorded.

The same method applies to peripheral field studies made on a campimeter or tangent screen. On the flat surface of the campimeter it sometimes is the custom to mark peripheral limits on the tangent surface. While this plan probably saves time, it is best to record on the chart the findings in each meridian as advised on the perimeter.

Color Examination.—It is immaterial in what order the patient is examined for color defects. It is, however, a good plan at all times to proceed in an orderly manner, and the blue, red and green fields are examined in the order mentioned and in the manner described for form, with these important differences: (1) Red, for example, may look pink to the patient when it is first observed in his field of vision, and he must be instructed not to call the color until he recognizes it as a distinctly red object. Thorough saturation is necessary. The same applies to blue and green. Inattention to this point may cause inaccurate results. (2) The average patient does not know that the red and green fields are narrower than form and blue fields, and very frequently there is a tendency on the part of the patient to answer too soon or glance from the fixation-point to the test object, and

thereby cause inaccurate results. (3) Before undertaking the examination of the color fields it is necessary for the operator to satisfy himself that the patient is not color-blind to one or more of the colors used in the test.

After carefully recording the results of the examination on a chart, for purposes of record, the fellow-eye is examined at the same sitting, and as nearly as possible under the same conditions.

Examination for Scotomata.—It is a part of the examination, after completing the limits of the field to test all parts of the field for blind spots known as scotomata. This can be done on each meridian with form and colors before one proceeds to the next meridian. While the picking up of a blind spot is not so readily accomplished on the perimeter as it is on the campimeter, such areas should be looked for on the perimeter and when found, the same should be submitted to a tangent screen for analysis. The same holds true of the blind spot of Mariotte. It is utterly impossible to make a satisfactory study of the blind spot of Mariotte on the perimeter.

The campimeter is ideally adapted to the careful outlining of scotomata. If the area to be examined is within the 30-degree circle, the smallest test object which the patient can recognize within this radius is used. Bjerrum recommended very minute objects for this test. By means of these small objects, a blind area is defined with greater accuracy than when the 1 or 2-degree objects are employed. Great care and patience are necessary to properly outline small scotomata. In the blind area the same color test should be made as in defining the extent of the field peripherally. In this test the color ceases to be recognized, although a zone of qualitative color change should be sought. For example, beyond the blind area for green there may be a zone in which the green object is seen as white and gradually takes on its color value as the test object approaches normal retina and choroid.

This indistinct zone should receive as much care as the area of relative or absolute blindness. In the earliest stages of the development of a scotoma an indistinct scotoma may be mapped out before a relative or absolute blind spot makes its appearance. In searching the field, therefore, for color defects, it is quite as important to determine qualitative changes in color in certain areas as quantitative.

To outline Mariotte's blind spot, or any scotoma centrally located, a 30-minute test object is most serviceable, providing the patient can see the object within the 20-degree circle. If the operator experiences difficulty in detecting a blind area, the patient's distance from the board can be increased to 1 meter, when the scotoma will be found to be increased in size proportionately and may be readily outlined. In fact herein lies the great advantage of the Bjerrum method.

Fixation in the Presence of a Central Scotoma.—When fixation is impossible because of the presence of a central scotoma, special methods must be employed. If vision in one eye is good, the Lloyd slate is the instrument of choice although other methods have been suggested from time to time. Most of these methods are based on the principle of binocular fixation. Von Szily used a funnel-shaped tube, through which the unaffected eye fixed. Walker of Springfield used a similar device. Schlösser covered one eye, for example, with a red glass, in making an examination for green, and *vice versa*. Duane recommends the same method. Tomlinson's scotomatograph with stereoscopic fixation and Haitz's stereoscopic charts are adapted for the same purpose. None of these methods is equal to the Lloyd slate.

When both maculæ are involved other methods must be followed. The fixation device on the Ferree-Rand perimeter is accurate. It is a more correct method than Reber's because it insures a correct position of the eye. By means of a peep-sight back of the perimeter the eye is first of all placed in proper position. The four points on the attachment are then moved toward

the center until they reach the outer boundary of the blind spot. By means of these four points, fixation is maintained and the examination proceeds as in normal fixation.

Reber's method is illustrated in Fig. 33. He recommended the drawing of a cross with lines at right angles. The patient is asked to look at the cross and the central lines are erased until the patient sees only the tips of the lines just beyond the blind area. These points are

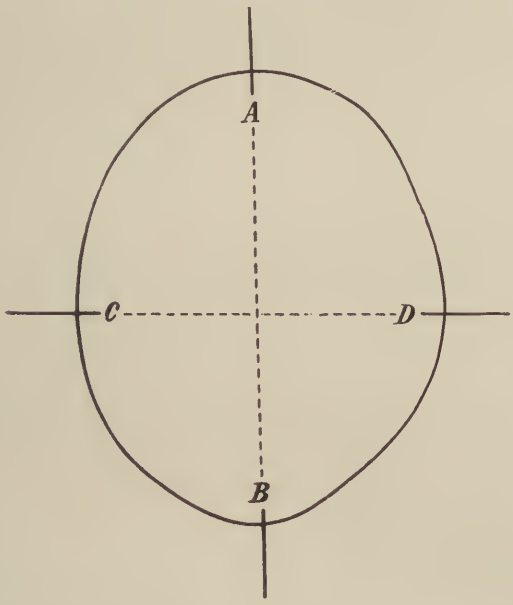


FIG. 33.—Diagram illustrating Dr. Reber's four-point method of fixation in mapping out a central scotoma.

used as a fixation as on the Ferree-Rand perimeter. The method does not insure perfect fixation, as the eye may, from the beginning, be misplaced.

A most practical method, and the one which is fairly free from error is the following one: The patient is placed before a perimeter or campimeter as usual with one eye bandaged. His index-finger is placed on the fixation-point and he is instructed to look at the end of his finger. Providing the person's muscle sense

is normal, this method is applicable to nearly all cases. In locomotor ataxia, it might not be applicable. If this latter method cannot be employed, the covered eye may be frequently uncovered to preserve central fixation, if the covered eye has fairly normal vision and the muscle balance is not much disturbed.

CHARTS AND METHODS OF CHARTING.

The chief value of perimetry lies in the charting of results for future study and comparison. These charts to be correct should be a miniature of the hollow sphere which the perimeter defines in the taking of the field. This is impossible, and we must be content with the projection of our results on to a flat surface, as in the Mercator projections of the earth's surface on maps. When the self-registering perimeter is used, the automatic device records the findings of the perimeter, providing the chart is carefully centered and the automatic device has been carefully adjusted. The latter trouble is a frequent source of error, and after restringing the instrument, it should be carefully inspected to make sure the recording needle has been properly centered.

The reader will note that the degree marks on the circumference of the charts will vary with each make of instrument. It is be deplored that more uniformity is not observed in the making of instruments and charts to correspond. The author finds the numbers as arranged on the McHardy and other modern instruments satisfactory, beginning with zero at the center of the chart above and ending with 180 degrees at the center of the chart below. Fig. 9 is the form of chart which the author finds most practical for recording purposes, and Fig. 34 for publication purposes.[1] Any size of chart which may suit the physician's fancy or purposes best may be employed, but uniformity in the matter of marking the degrees should be carefully observed. For the campimeter, special charts which are an exact

[1] The latter chart is on cardboard 9 by 14 inches.

reproduction of the campimeter should be employed, although the regulation chart used on the arc perimeter will be found satisfactory.

For the author's campimeter, the special chart should be employed. This chart is an exact reduction of the campimeter, and has the advantage of being cleanly cut and less covered with unnecessary lines, thereby allowing defects in the field to be seen more clearly. On this chart is drawn with great care and accuracy the size of the normal blind spot, so that the slightest increase in its size may be noted.

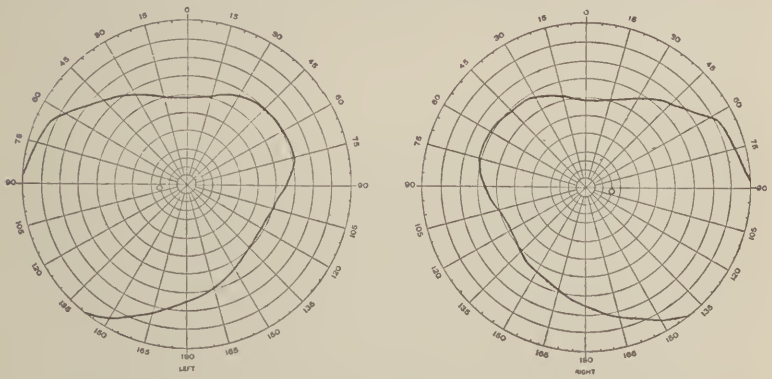


FIG. 34.—Form of chart best adapted for reporting of cases.

RECORDING OF FIELDS TAKEN ON A NON-REGISTERING PERIMETER.—The average student finds it difficult to transfer the readings from the perimeter to the chart. The matter can be simplified by bearing in mind that the recording chart is a miniature of the perimeter. Hold the chart back of the perimeter facing the patient, as the semicircle of the perimeter faces him, and the chart will be in a position which will at once remove the difficulty. The meridians designated on the back of the perimeter will correspond to the reading on the circumference of the chart. For example, when the arm of the quadrant is at the 45th meridian to the right of either eye examined, the 45th meridian on the chart to the right as the chart is held before one is the meridian sought. The

most peripheral point on the quadrant at which the patient can see the object can be read off from the back of the quadrant, and the mark is made on the 45th meridian on the chart at the degree designated on the quadrant, reading from the center of the chart to the periphery. Example: The 45th meridian to the right of the right eye is under investigation. The patient sees the object at 50 degrees from the center. A mark is therefore made on the chart of the right eye at the intersection of the 50th degree and the 45th meridian.

Campimetric Charts.—If the campimeter is marked in circles, the charts employed in perimetry may be used, or the author's campimetric chart may be substituted. If, however, the board is divided into squares, charts must be especially drawn as a facsimile of, or a miniature of the blackboard. The transfer of these fields to the chart will not give rise to any difficulty.

Elliot's scotometric charts are designed for use on his instrument, Fig. 30. As the calculations are technical, the interested reader is referred to Col. Elliot's own instructions in reference to the same.

Charts for the Lloyd slate are an exact reproduction of the slate surface and require no special instructions in their use.

Data to be Recorded on Charts.—Perimetry is but a handmaiden to ophthalmology. In itself it is incomplete, but when associated with certain other facts, it becomes indispensible. In addition to carefully charting on the diagram changes which may be found, other data are essential to an intelligent interpretation: (1) Central vision of each eye is of prime importance; (2) the ophthalmoscopic diagnosis, if possible, should be recorded; (3) the size of the test objects used and the character of the light should be noted; (4) indistinct and irregular forms of scotomata will require a description; (5) the radial length of the instrument should be recorded; (6) the name of the patient, date, and reference to patient's history records should be noted on the chart.

PART IV.

GENERAL PATHOLOGY OF THE VISUAL FIELD.

THE pathological changes which one notes in examination of fields are of a twofold character: (1) scotomata, or blind spots; (2) changes in the size and shape of form and color fields. Either one of these changes may be observed separately in a given case, or they may be found in combination.

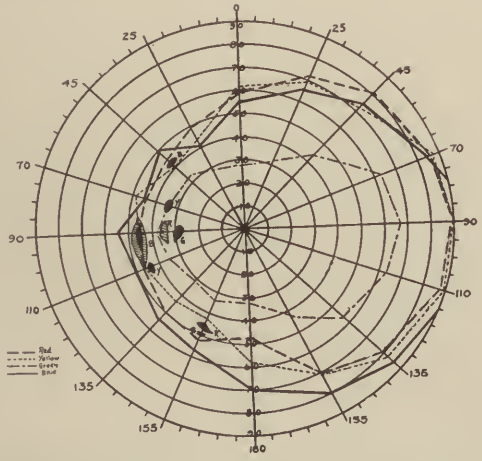


FIG. 35.—Schumann type of color-blind areas, showing small areas in the peripheral field of a normal eye in which there is blindness to one color. These areas are represented in black, with letters to indicate the colors to which there is a deficiency. In case there is total color blindness to the stimulus used, the area is represented in solid black; in case there is only marked depression of sensitivity, the area is shaded. In this latter case areas are represented only when the depression amounts nearly to blindness). Ferrie-Rand.)

SCOTOMATA.

A scotoma is a blind spot which appears in the visual field. The blind spot of Mariotte is the only

area in the field of the normal eye which may be regarded as normal, as it represents the entrance of the optic nerve into the eyeball—an area in which the rod and cone elements are absent. Any other areas within what may be regarded as normal limits of vision for a given patient are pathological;[1] and represent alterations in function or structure of parts of the visual pathway. They may be small or large, regular or irregular in outline, distinct or indistinct, as the lesion which causes them will determine.

INDISTINCT, RELATIVE AND ABSOLUTE SCOTOMATA.—In order to be specific in describing the character of blind spot, we classify scotomata, first, as indistinct, relative and absolute.

Indistinct Scotoma.—Occasionally a scotoma is indistinct in outline, *i. e.*, the patient is unable to define a sharp line of demarcation between the point of clear vision and the absence of vision. Surrounding a relative blind spot, this is especially well illustrated. In a blind area for green, for example, the color does not sharply disappear as the blind spot is approached, but it shades off into a paler green, becomes white and is finally lost. The periphery of a scotoma, therefore, is surrounded by an indistinct zone and we speak of this area as an indistinct scotoma. The entire partially blind area may be of the same general character, in which green, for example, may not be recognized as a color, or in which even form may be hazy and uncertain. This latter variety should also be classified as indistinct. In fact great care and exactness in the choosing of terms which we employ in describing definite conditions, is essential to a clear interpretation. There is no fixed rule for charting an indistinct scotoma. The

[1] J. Schumann (Bericht über den I. Kongress für experimentelle Psychologie in Giessen, 1904, pp. 10–13) reported an unusual case of spots of color blindness, and Ferree and Rand (Journal of Experimental Psychology, August, 1917, 2, No. 3) contributed additional cases of the Schumann type of color blindness. See Fig. 35. They are as a rule very small and require most careful technic in order to demonstrate their presence.

author uses an oblique line as shown in Fig. 36. It is best, however, to note on the chart the word "indistinct."

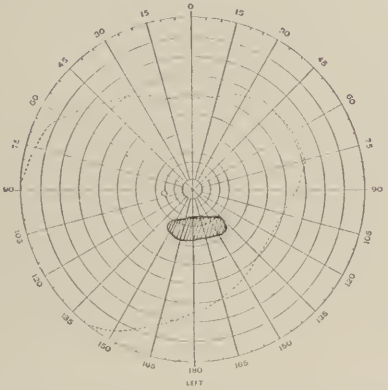


FIG. 36.—An indistinct scotoma.

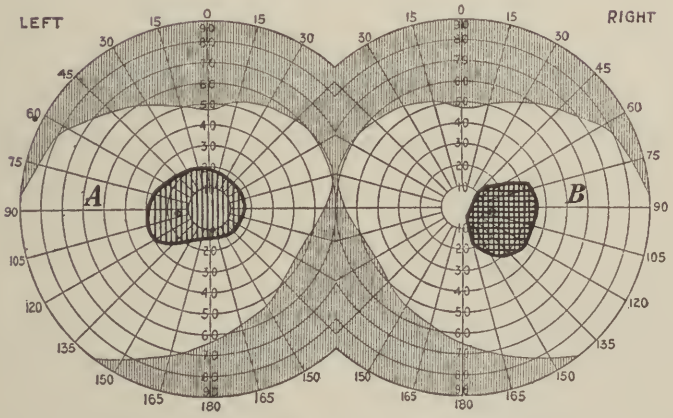


FIG. 37.—*A*, central scotoma. Method of charting a relative scotoma. *B*, paracentral scotoma. Method of charting an absolute scotoma.

Relative Scotoma.—A relative scotoma is an area in which form may be seen, but in which one or more colors—blue, red or green—are not recognized. The uniform method of charting a relative scotoma is represented in Fig. 37, *A*. Parallel lines are drawn in a horizontal or vertical direction.

An Absolute Scotoma.—An absolute scotoma is a blind area in which the patient cannot perceive form, color or light. It is a totally blind area in which light sense is totally absent. In charting this form of blind spot, it is universally drawn as in Fig. 37, *B*. When charted in this manner, it needs no further description.

The difference between an indistinct, a relative and an absolute scotoma is practically one of degree. In the course of development, if the process is not too acute, an indistinct area develops first, followed by relative changes and finally a blind area appears which is absolute. In recovery, too, before function is completely restored, an absolute scotoma will become relative; or if recovery remains incomplete, a relative or an indistinct blind spot may remain. The completeness or the incompleteness of a scotoma, therefore, enters not only into the diagnosis but into the prognosis as well.

Positive and Negative Scotomata.—A second classification is that of positive and negative scotomata —a classification which is frequently confounded with that of relative and absolute. The characteristics here are totally different. A positive scotoma is a blind area in the visual field which the patient sees entoptically—a black or gray area which the patient can clearly outline, and of which he will complain when the oculist is consulted. A negative scotoma, on the other hand, is not recognized by the patient, and is only elicited by careful examination on the perimeter. A positive scotoma may in time become negative, *i. e.*, after a considerable period of time the patient may become so accustomed to the presence of the blind area that he is no longer conscious of it. Floating masses in the vitreous give rise to positive scotomata in the visual field, but in time they may disappear from the patient's consciousness, and no longer interfere with vision. The classification, however, has a deeper significance. Positive scotomata usually mean a lesion, or lesions, which prevent the formation of an image on

the rod and cone neuron, as, for example, a dense hemorrhage in the retina or vitreous, disturbance of the choroidal circulation, or circumscribed disease of the choriocapillaris which supplies nourishment to the rod and cone elements. Under these circumstances, the blind area is likely to be positive. On the other hand, a negative scotoma usually is associated with disease of the neurons, the ganglionic elements, or of the axis cylinders. In recent cases this location of the lesion by the positive or negative character of the blind area may, in a majority of cases, be depended upon. In cases of long standing, however, a positive scotoma may become negative, as explained above.

It must be clear also that negative scotomata may be indistinct, relative or absolute.

Central, Paracentral and Peripheral Scotomata.—A third classification may be made in reference to position, that of central and peripheral. A central scotoma is one which includes the macula, a condition which is common in retrobulbar neuritis or toxic amblyopia in which the papillo-macular bundle of nerve fibers is diseased. Peripheral scotomata, as the name implies, are found in peripheral parts of the retina. When in the center or intermediate zone, that is up to the 40th degree from the center, they are readily recognized by perimetry; but when in the extreme periphery, where the retinal elements require strong stimulation in order to receive a visual impression, they are often overlooked unless searched for carefully. Scotomata in the central zone may be subdivided into pericentral (around the macula) or paracentral (alongside of the macula).

Cæco-central Scotoma.—If a scotoma includes the blind spot of Mariotte and the macula, it is sometimes spoken of as a cæco-central scotoma—a convenient term which is self-explanatory and brief.

Enlargement of the Blind Spot of Mariotte.—The normal blind spot varies within normal limits, depending upon anatomical differences, types and

physiological variations. The shape of the average disc is oval with the long axis in the vertical. The exact shape of the blind spot, however, depends upon the attachment or the extent of the choroid and retina. The retina may be close to the scleral edge in one part and somewhat distant in another. This irregularity will naturally cause an irregularity in the shape of the blind spot. In round figures Van der Hoeve found the average blind spot to measure 7 degrees in length and 5 degrees in width. This agrees with the author's studies. Considerable variation has been recorded but the figures given are actual measurements. Van der Hoeve and others found a narrow band of indistinct scotoma surrounding the absolute area. This area rarely exceeds 1 degree in width and by ordinary clinical methods is not uncovered unless studies are made at a radius of 1 or 2 meters. In ordinary clinical work, therefore, an appreciable indistinct or relative enlargement must be regarded as of pathological significance. In pathology of the blind spot the appearance of this indistinct band is an early sign of disease. Then follow enlargements which are relative or absolute as the case may be.

The direction in which enlargements take place is of much importance. In myopia for example and in toxic amblyopia, the enlargement is toward the point of fixation. In glaucoma enlargements are observed from above and below and toward the center of fixation—the so-called Seidel sign. The increase in this instance is in the direction of the nerve fibers which pass above and below the macula toward the raphé. In sinus disease the enlargement is more or less concentric, like an iris diaphragm.

Enlargement of the temporal border should always be studied most carefully, as it is in this area that the patient finds the greatest difficulty in giving decisive answers. There are two reasons for this, if very small tests objects are used. In the first place the outer edge of the optic disc is 5 or 6 degrees further from the

center than is the inner edge. This part of the retina is relatively less sensitive to low or medium intensities of stimulation. A second reason may be found in the fact that nerve fibers and bloodvessels are pushed to the temporal side of the disc, and while they should not decrease the relative sensitivity of the retina, many superimposed fibers may contribute some to rendering the immediate zone a little less sensitive than other areas adjoining.

Abnormal positions of the blind spot, *i. e.*, a blind spot displaced out or in, can hardly be called pathological. Excepting in myopia, in which the blind spot is apt to be nearer to the point of fixation than normally, such displacements should be regarded as physiological or anatomical variations.

The reader may ask, what constitutes a pathological enlargement of the blind spot? By the ordinary clinical methods, an increase of two degrees should be regarded as pathological, especially if the other eye does not show the same increase in size or the ophthalmoscope does not reveal a disc of unusual proportions. If the operator is in doubt, careful studies should be made at a meter's distance when an increase in the relative and indistinct color zone will assist materially.

Ring Scotomata.—Under certain conditions a scotoma, or blind spot, may take the form of an irregular or an incomplete circle. This form of visual defect usually is found in the intermediate zone between the 15th and 30th degrees. Much thought has been given to the reasons for the formation of this defect. It is in this zone that the short ciliary arteries terminate, and this factor, together with the peculiar arrangement of the chorio-capillaris, probably more than any others, gives rise to the ring scotomata. The exact manner of formation is unsettled. This scotoma rarely develops as a ring primarily, but island-like blind areas are first in evidence. These enlarge, and finally coalesce to form a complete or incomplete area of blindness about the point of central fixation. Instead

of completely encircling the macula, a healthy choroid and retina may extend in one area from center to periphery, forming thereby a horseshoe-shaped scotoma (see Fig. 38). When recovery takes place, the ring scotoma again resolves itself into islands, and if recovery is incomplete, multiple scotomata may remain to mark

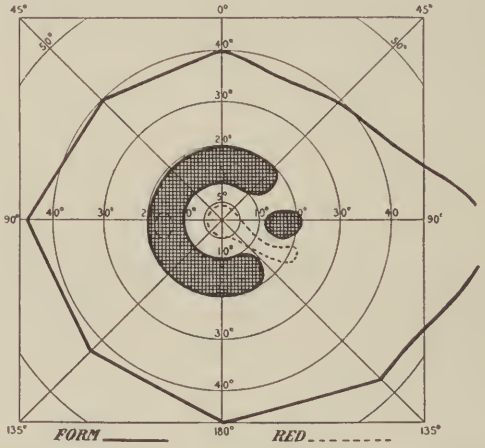


FIG. 38.—A ring scotoma of syphilitic origin. Enlarged blind spot of Mariotte.

the site of the ring scotoma. This type of blind spot is usually of vascular origin. Syphilitic choroiditis is a common pathological factor. Other general and constitutional diseases which produce vascular changes are also associated with this type of blind spot. It may be assumed, therefore, that the choroidal circulation

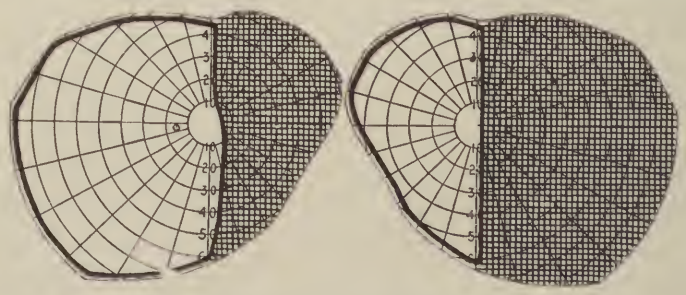


FIG. 39.—Homonymous hemianopsia.

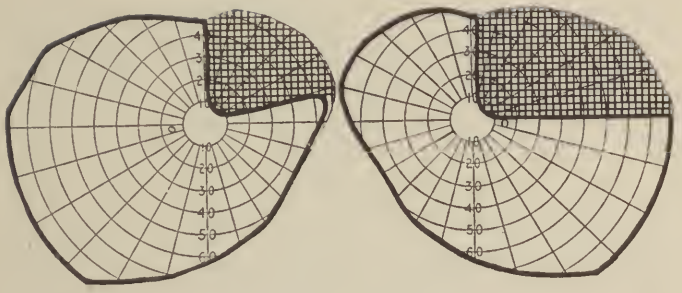


FIG. 40.—Quadrant anopsia.

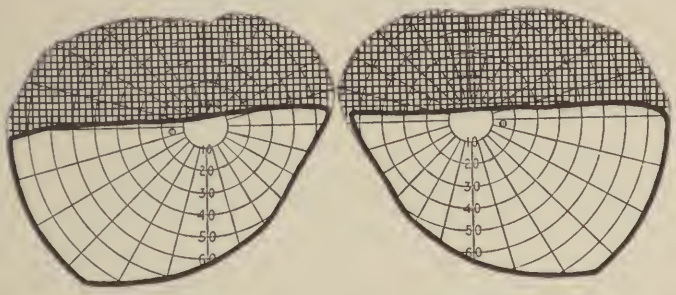


FIG. 41.—Altitudinal hemianopsia.

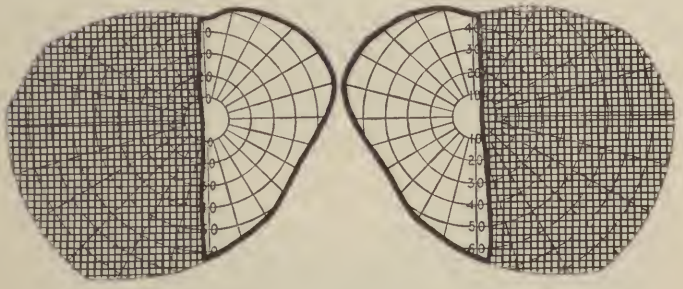


FIG. 42.—Bitemporal hemianopsia.

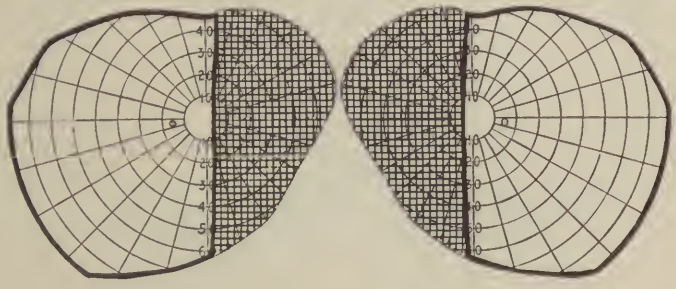


FIG. 43.—Binasal hemianopsia.

FIGS. 39 to 43.—Types of anopsias.

is usually at fault, and rarely the neuron elements. A ring scotoma may be formed in commotio retinæ. The retina is firmly attached to the sclera at the entrance of the optic nerve and at the ora serrata. Between these points of fixation the retina is loosely attached to the underlying tissues; and the formation of a ring scotoma, therefore, as pointed out by Lohmann, is easily understood, as circulatory disturbances or detachment may occur between, or at some distance from, the optic nerve and ora serrata.

Instead of disease of the retina and choroid, ring scotomata may have their origin in the optic nerve, the chiasm or the brain. Under these circumstances, one or both eyes may be involved; the location of the lesion in each instance will determine this fact.

Quadrant and Hemianopic Scotomata.—Anopsias.—Disease of the visual pathway in the chiasm or in any part posterior to the chiasm is characterized by certain field changes known as anopsias. They are bilateral changes, although rarely in chiasmal disease but one eye may be affected. As a rule corresponding retinal parts are involved. When an entire half-field is blind the condition is one of *hemianopsia*. When but a quarter of the field is blind the condition is known as *quadrant anopsia*, right or left superior or

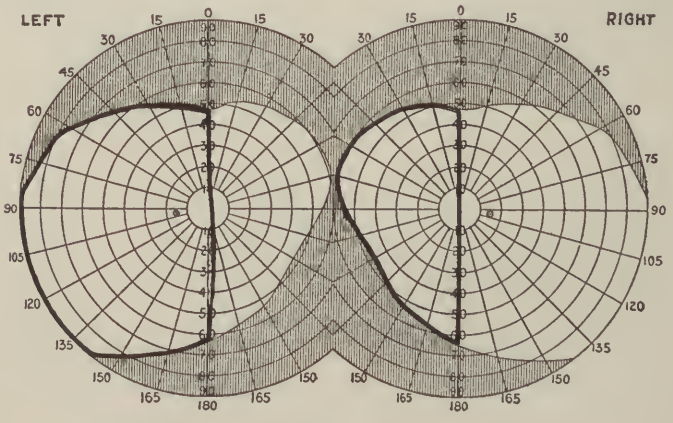


Fig. 44.—Dividing line close to center.

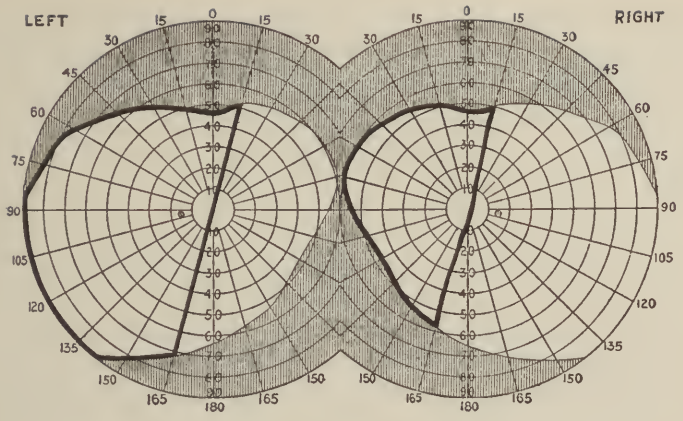


FIG. 45.—Oblique dividing line.

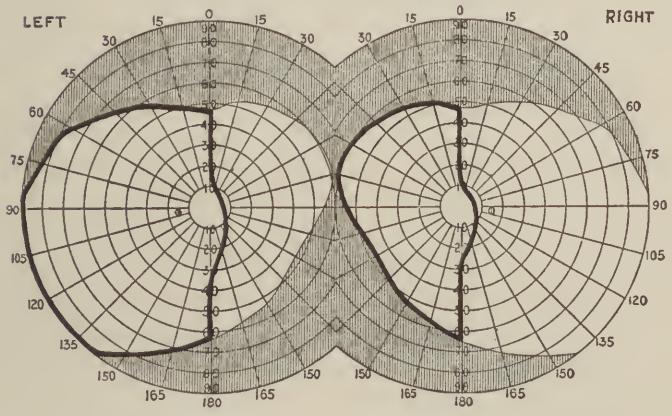


FIG. 46.—Macular area and area beyond macula intact.

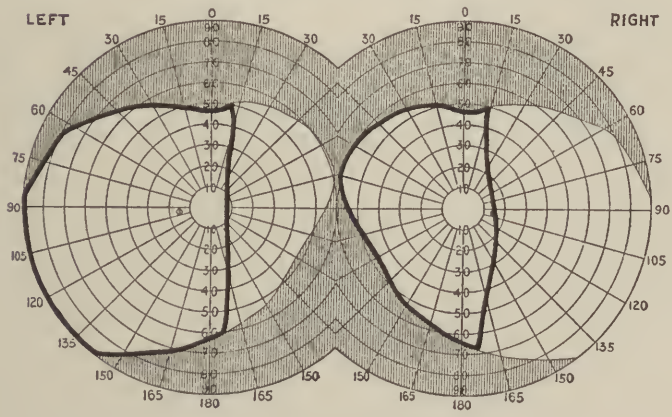


Fig. 47.—Overshot fields.

FIGS. 44–47.—The dividing line of homonymous hemianopsias.

inferior. The anopsias are *homonymous* in type when the right or left half of each field is blind, *heteronymous* when the temporal halves or nasal halves are involved. Blindness in both temporal fields is known as *bitemporal hemianopsia* and in both nasal fields as *binasal hemianopsia*.

Anopsias may develop from the periphery toward the center or they may begin as homonymous or heteronymous scotomata in the central field, and spread toward the periphery, or both processes may be combined.

Instead of a lateral division of the blind and seeing parts of the retina, the dividing line may be horizontal. When the upper or lower half is blind, the anopsia is known as *altitudinal hemianopsia*, superior or inferior.

Anopsias may be indistinct, relative or absolute, negative, and rarely, positive.

Line of Demarcation.—The dividing line, or line of demarcation, between the seeing and blind parts of the retina is best determined by Bjerrum's method, a small (5′ to 30′) test object being used. Because of individual anatomical differences in the distribution of the crossed and uncrossed nerve fibers in the chiasm, the dividing line will not be the same in all cases. In Fig. 44 the line of demarcation is straight and passes close to the center. In Fig. 45 the dividing line is oblique. Either of these types may be found, and they are due to this anatomical difference to which reference has been made. Again, because of the alleged double innervation of the maculæ in certain conditions, a hemianopsia may pass around the macula, as in Fig. 46, or we may find "overshot" fields, as shown in Fig. 47. In this type of field, according to Wilbrand,[1] not only are the maculæ intact, but the field above and below the macula is preserved because of the anatomical abnormality of the distribution of the crossed and uncrossed fibers.

[1] Norris and Oliver, vol. 2, p. 265.

It is interesting to observe that color sensitivity is normal in the preserved field up to the dividing line for form. When color fields fall short of the dividing line for form, it is evidence that the diseased part of the brain is not limited to one hemisphere; that the other hemisphere is involved either by extension or by pressure.

Significance of Overshot Fields.—Careful studies of overshot fields, by Wilbrand and others, show that the color fields extend to the extreme limits of the form field or dividing line when the preserved form field extends beyond the line which passes through the macula. This is conclusive evidence, according to Wilbrand, that destruction of the hemisphere or the fibers coming from the hemisphere which represents the blind half is complete. If incomplete, color fields would not extend up to the normal but would show some shrinkage. According to the same author it confirms his convictions that an overshot field has representation in each cortical optic center, and that there is a double provision for the maculæ.[1] In other words not only the maculæ but other parts of the retinæ may be preserved in complete hemianopsia. Wilbrand cites a case in point, in which the overshot area included not only the maculæ but to the same extent the retina above and below the maculæ. This occurred in a woman, aged twenty-four years, who suffered from complete right-sided hemianopsia from early childhood. At autopsy the left occipital lobe was found to be a "crumbling mass" and descending atrophy was observed in the left optic tract deep into the chiasm, showing that the overshot field bore a distinct relation to the centers and conduction path. See Figs. 48 and 49.

Intact maculæ are a frequent occurence in homonymous hemianopsia—in fact the rule rather than the exception. Properly substantiated overshot fields

[1] Norris and Oliver, vol. 2, p. 280.

with autopsy are exceedingly rare. The condition is most difficult to comprehend according to our present

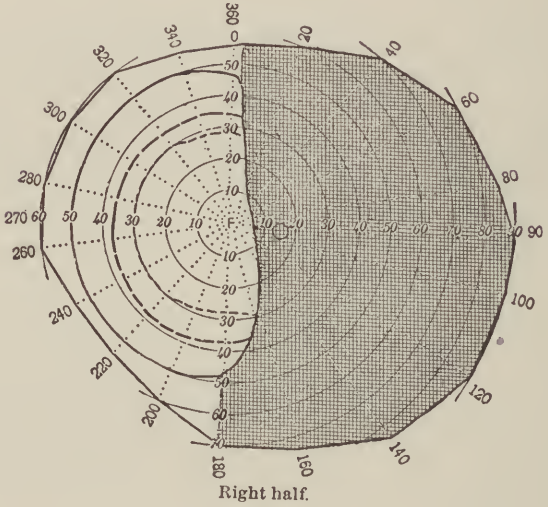
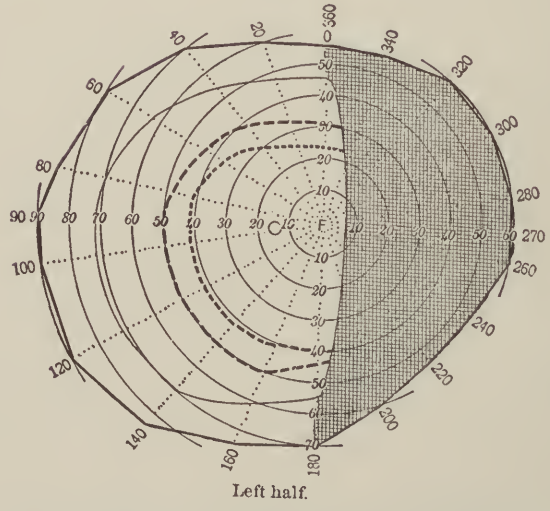


FIG. 48



FIGS. 48 and 49.—Wilbrand's case of overshot fields.

belief as to cortical representation. Future studies and contributions may help to give us a better under-

standing of the subject. For the present at least it remains *sub judice.*

Incomplete Hemianopsia.—Rapidity of onset, completeness or incompleteness of homonymous types of hemianopsia vary with the character of the lesion and its location. The internal capsule is a part of the visual pathway which is frequently involved in pathological vascular changes. In this area the visual disturbances are sudden in onset, sometimes completely hemianopic from the beginning with a tendency to improve, the resulting defect being quadrantic or sector like. These types are usually associated with motor and sensory symptoms unilateral in character. In lesions of the posterior part of the brain, not infrequently neoplastic in origin, hemianopsias are incomplete at first, quadrantic or even sector like, with a tendency to increase as the new growth or lesion develops. This incomplete type, with a tendency to increase, is especially apt to occur in lesions of the posterior part of the brain. If sudden vascular changes develop in the area, just as in lesions in and about the internal capsule, the hemianopsia may be complete from the beginning and show signs of regression or remain complete.

Color Homonymous Hemianopsia.—Hemianopic color defects or scotomata without form changes have been recorded. With the improved methods of studying fields, it is likely that some defect in the form field will be detected which older and less accurate methods have failed to reveal. We have no assurance that there are separate pathways for carrying of color impulses nor have we any knowledge of special cortical centers for color perception. Without separate pathways and separate centers there should be no frank color defects in which form changes cannot be elicited by quantitative perimetry. It is true that color changes are more sensitive and color contraction may be more marked than that for form, but minute white stimuli will be apt to demonstrate that form changes are present in these so-called neurological cases.

Scotomata Associated with Peripheral Field Changes.—The various form of scotomata thus far described may or may not be associated with the second type of change in the field, namely, alteration in form and color fields. For example, in toxic amblyopia, one may find the classic central scotoma together with contraction of form and color fields; and in hemianopsia, instead of normal fields in the seeing half, one may find shrunken fields, especially when the lesion is near to or in the chiasm. Again, a lesion in the posterior part of the brain, especially neoplastic in origin, may be so large as to give rise to increased intracranial pressure. Under these circumstances, in addition to the direct focal symptom of hemianopsia, the general symptoms, papilledema and optic neuritis, may cause a contraction of form and color fields in the part of the field which is unaffected by the hemianopsia.

The presence of hemianopsia does not eliminate the possibility of hysteria in the same patient. In addition, therefore, to the symptom of hemianopsia, one may find those of hysteria. The same rule applies to all the various changes which may be found in a patient suffering from combined systemic disease and independent conditions which may cause hemianopsia.

CHANGES IN FORM AND COLOR FIELDS.

Three types of changes are found in the shape and size of the fields: (1) There may be a concentric contraction of the field; (2) in addition to the concentric contraction, one or more parts of the field may show angular or irregular areas of greater shrinkage; (3) the field for the most part may be normal, and a large irregular angular defect may extend in one area, even to the point of fixation. All irregularities in the form fields will fall under one of these divisions.

Concentrically Contracted Fields.—An uncomplicated, or primary optic atrophy furnishes the best example of concentric contraction of form and color

fields. In the early stages of the disease there will be found moderate and equal contraction of the form field in all directions. Color fields are also reduced, at times relatively, but more frequently out of proportion to the form field. The essential feature is the concentric contraction. For example, in Fig. 50 the form field is contracted approximately to 50 degrees on the temporal side, and red is recognized at 30 degrees, whereas green has entirely disappeared from the field. Blue, on the other hand, is nearly as large as the form field. As pointed out earlier, blue is not involved

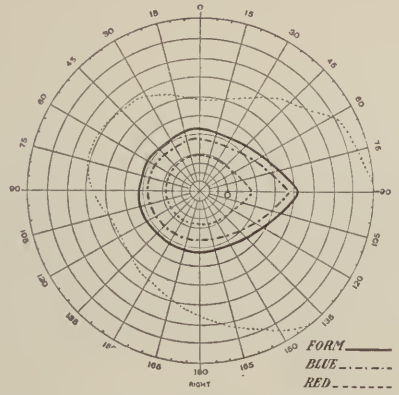


FIG. 50.—Concentrically contracted field of primary optic atrophy. Green field totally lost.

so early in neuritic diseases as in chorio-retinal disturbances. The reverse is true of red and green. In fact, in primary optic atrophy, shrinkage in the red and green fields may be apparent before the form field has diminished in size. This is true when the field is taken in a good light. In reduced light, a contraction of the form field may be clearly demonstrated, while red and green will show a relatively greater reduction. The concentric element in the contraction, however, is the chief characteristic of this type of change. When present, it means an evenly distributed atrophy or disease of the optic nerve.

Concentric Contraction Plus Unequal Defects. —The second type of contraction is found most typical in optic neuritis. In this condition, while the entire nerve is the seat of disease, an area may show greater destruction, and the field still show one or more re-entering angles of contraction. This type of field is probably the one most frequently observed, as one rarely sees an evenly diffused inflammation of the optic nerve. Furthermore, the peripheral parts of the retina are not equally sensitized for two reasons: (1) Anatomically, both blood and nerve supply are more direct and shorter to the nasal side of the retina than

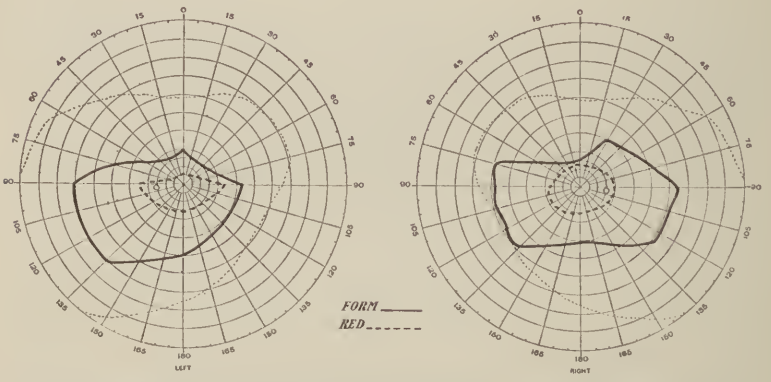


Fig. 51.—Irregular contraction of optic neuritis. Loss of upper field with general contraction.

to the temporal side. Hence, in glaucoma, whether acute or chronic, one might expect to find a concentric contraction, but as a rule the nasal field is always the first to show shrinkage; (2) the rod and cone elements on the nasal side of the retina are in greater activity and more sensitive to impressions than the temporal elements. A somewhat irregular field, therefore, is most frequently observed. The behavior of the color field in this instance is not unlike that of the first type, *i. e.*, the color fields follow the form fields rather regularly, showing only a somewhat greater degree of shrinkage.

Normal Fields with an Entering Angle.—Possibly the third type of change might be considered an advanced stage of number two. As a matter of fact it may eventually assume pretty much the same characteristics as the second type, but primarily it is distinct. It is well illustrated in glaucoma, in phlegmon of the orbit or in disease of the sphenoidal accessory sinus. The sphenoidal sinus is separated from the optic nerve in the optic foramen by a thin partition of bone. In disease of the sphenoid a localized inflammation of the nerve may therefore mark the beginning of what will become diffused optic neuritis, and the type of field under discussion may be observed. Disease of the orbital tissues along the course of the optic nerve, or even in the chiasm, may produce the same type of field. As a rule the condition is unilateral, unless both orbital cavities are involved or disease of the chiasm develops. It signifies focal disease in the course of the optic nerve, chiasm, or more rarely of the tract, or an intraocular condition such as chorio-retinitis juxta papillaris. It is most typically observed in the so-called Bjerrum sign in glaucoma. As a rule, color defects of a similar character will be observed.

Changes Peculiar to Colors.—Contraction of the form fields shows the degree of disease of the visual tract. It is better evidence of the real condition of the visual path than an ophthalmoscopic study can possibly furnish. The evidence is minute and analytical. The color fields and color changes, however, furnish a more delicate test in the early stages of the disease and at times furnish the clue to the seat of trouble before an appreciable change has taken place in the form field. Lohmann quotes Köllner's observation of green vision in a patient for weeks before retinal detachment occurred. Color changes in general are earlier than those for form, and a careful study of the behavior of colors in various parts of the field has increased the clinical value of perimetry both in diagnosis and prognosis. Studies in color fields show, for

example, that blue is more clearly observed in indirect vision than in the macula. A red object 2 mm. in diameter can be clearly defined in a good light at 6 meters. A 5 mm. green object may be recognized at the same distance, while but few patients can recognize a blue object 7 mm. in diameter at this distance. When, however, a 7 mm. blue object is placed 15 cm. eccentric to the point of fixation, it can be clearly recognized as blue at 6 meters.

In diseased conditions, this peculiarity of the behavior of colors becomes accentuated and, paradoxical as it may seem, the blue defects may be observed in central vision earlier than in the periphery. It is a matter of observation also that blue and yellow changes may be the earliest changes noted in disease of the retina and choroid, *i. e.*, in disease of the neuro-epithelium; red and green contraction is a much later phenomenon than that of blue and yellow. In disease of the conducting paths and centers, on the other hand, blue and yellow may be preserved after red and green have been lost, or at all events, shrinkage of the blue and yellow follows that of red and green.

Inversion of Color Fields.—Under certain conditions, usually functional in type, the order of the size of color fields is reversed. For example, in hysteria, the green field may extend beyond the limits of the red field throughout, or more frequently the size of the red and green fields will be the same. Red and green reversal, or interlacing, may be looked upon as functional in origin. Reversal of blue and red or blue and green, however, may be, and usually is, organic in origin, or at least, if functional, is due to circulatory disturbance. In chorio-retinal disease, for example, especially when the elements of edema are present in the retina as in chronic interstitial nephritis, the blue field may be contracted within the limits of the red, and even the green. (de Schweinitz and others claim the blue-red inversion is quite as common as the red-green inversion, and that the red field in particular

is apt to be enlarged.) If, however, the blue-red or blue-green inversion is a symptom of hysteria, other ocular symptoms of hysteria may be present as, for example, *tubular fields*, and the eye-ground will be negative. A type of apparent or partial interlacing of the color fields may be due to lack of care in taking the fields. The patient's head may be allowed to shift, or the eyes may wander so that the position has not been the same throughout the examination. Most incomplete or partial reversals of color fields may be found to be due to this cause; and when such a field is developed, the field should be reëxamined carefully to avoid this source of error or to confirm the correctness of the field. Ferree and Rand believe that the blue and red fields interlace normally. In the studies which led them to this conclusion, Herring papers were used. The author has employed the Heidelberg papers and has never been able to find interlacing of these colors in the normal with moderate intensity of the stimulus. It is entirely possible to select certain hues of red and blue which will show similar peripheral limits. On the other hand, the author believes that it is possible to select other hues of red and blue which will not interlace. All clinical evidence tends to establish the fact that blue is more readily seen in the extreme periphery than is red, if the same size disc and the same illumination are employed. While further normal studies may reverse our present clinical belief, for the present at least, the evidence thus far produced does not seem to be sufficiently convincing to change the generally accepted order of white, blue, red and green.

Tubular Fields.—Under normal conditions, when the patient's eye under examination is removed farther and farther from the central object on the perimeter, the field will increase proportionately in size. The angle of vision is the same, but the base of the triangle which the angle subtends will increase with the length of the sides of the triangle.

If *A* in Fig. 52 represents the width of the field at 33 cm., at 1 meter the field is represented by *B*, at 2 meters by *C*. In hysteria, instead of a normal increase in the size of the fields, approximately the same size will be developed for all distances, even up to 2 meters. In fact, in this condition, form and color fields may appear to be the same size. This is not the result of malingering on the part of the patient, even though it may seem so to the casual observer. It is in entire keeping with the general symptomatology of hysteria, *i. e*, the element of inhibition dominates the patient's conduct throughout. This type of field, together with other symptoms will be more fully discussed in the section on Functional Nervous Diseases.

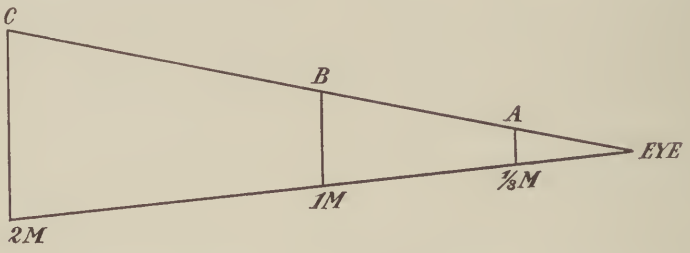


FIG. 52.—Diagram illustrating the size of the field at distances of ⅓ meter, 1 meter, and 2 meters.

FATIGUE FIELD.—A condition of exhaustion is readily manifested in the study of fields. Even in a normal case, too prolonged an examination will develop a field modified by exhaustion. In low asthenic states, and especially in pronounced neurasthenia, a type of field may be developed which differs from all other changes and is characteristic of neurasthenia. The most typical form of field in this condition is known as a spiral field. The rods and cones in the peripheral parts of the retina are first affected in asthenic states, and the condition gradually increases toward the center as the state of exhaustion increases. When, therefore, a field is taken, the first points examined may approximate the normal in size, but as

the examination continues, the evidence of exhaustion becomes more and more pronounced, as shown by the increasing contraction of the field. If the examination is repeated several times, the boundary lines of the field will assume the shape of a spiral curve, growing smaller as the examination is continued. Such a field is represented in Fig. 53.

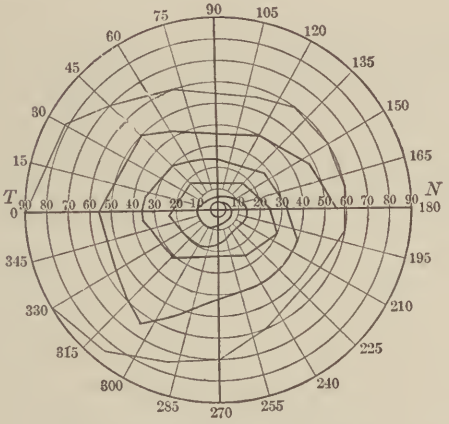


FIG. 53.—Spiral fatigue field of von Reuss. (Potts.)

In the normal patient, the field tends to enlarge with each successive examination, or as the patient develops a better understanding of what is expected of him in the taking of the field. However, if the examination is continued for too long a period, so as to cause physical tire, the field may show a slight tendency to contract as the result of normal tire.

Scintillating scotomata, photopsias, etc., will be discussed in the section on Functional Nervous Diseases.

PART V.

SPECIAL PATHOLOGY OF FIELDS.

A STUDY of changes observed in specific instances of organic disease can be made most systematically by dividing the visual pathway into: (*a*) The intraocular portion, including the choroid, retina, and nerve head; (*b*) the optic nerve proper; (*c*) the chiasm; (*d*) the intracerebral portion, including the optic tract, primary optic centers, optic radiation, and the cortex concerned in vision. This division of the visual pathway is a natural one, anatomically, physiologically, and pathologically.

DISEASES OF THE INTRAOCULAR PORTION OF THE VISUAL PATHWAY.

It is a difficult matter in most instances to draw a sharp dividing line between diseases of the choroid and retina. In fact, one does not think of disease of the choroid without a secondary retinal involvement. As pointed out in the anatomy and physiology of the visual path, part of the function of the choroid is to supply nourishment to the neuro-epithelial layer of the retina. Disturbance of function in one implies disturbance of function in the other. At times, when changes are minute, the ophthalmoscope fails to definitely locate the site of disease. Perimetry therefore may be of particular value in such instances.

Perimetrically, there are two general symptoms which especially aid us in differentiating between primary disease of the choroid and of the retina. Shrinkage or loss of the blue field, out of proportion to the red and green, is characteristic of choroidal disturbance and disturbance of the rod and cone

layers of the retina. Contraction of red and green, with fairly normal blue and form fields, on the other hand, is characteristic of changes in the inner layers of the retina and the ganglionic axis cylinders which form the optic nerve. The behavior, therefore, of the blue, red and green fields may be the key to the differentiation between disease of the choroid and retina, when ophthalmoscopic symptoms are doubtful.

A second broad perimetric difference between disease of the choroid and the outer layers of the retina, and disease of the ganglionic and nerve fiber layers of the retina, is in the character of the scotoma when present, especially in the macular region. Lesions of the choroid and rod and cone layer may be accompanied by a positive scotoma, or a blind area of which the patient is conscious. On the other hand, disease primarily in the inner neuron, that is, in the ganglionic cells and their axis cylinders, is accompanied by a scotoma which, as a rule, is negative in character, a blind area of which the patient is not conscious. With this broad differentiation in mind, one may at times determine with precision the primary site of disease in the eye, even though the ophthalmoscopic evidence may be negative.

Clinically, one observes at times in choroidal disease a contraction for red and green equal to, or greater than, that for blue, and a negative scotoma instead of a positive one. When these phenomena are present, it is probable that the inner neuron of the retina has become involved as well as the outer neuron and the choroid.

Notwithstanding the usual secondary involvement of the retina in disease of the choroid, one finds distinct types of disease in which only one of these elements is involved, or in which the symptoms of one so overmask the secondary involvement of the other as to obscure its presence.

Choroiditis.—In all types of choroiditis, as a rule, perimetric deviations from the normal will be found to correspond to the pathological changes observable with

the ophthalmoscope. Occasionally, in recent choroiditis, with only moderate absorption of retinal pigment, the ophthalmoscope may fail to reveal the disease. In such areas, a qualitative disturbance of the blue field may be made out by perimetric studies. Any part of the choroid may be involved. The characteristic perimetric evidence, therefore, of choroiditis is multiple scotomata distributed irregularly over the field, usually positive, although sometimes negative in character—relative in the early history of the case, and absolute as the disease progresses. In the syphilitic forms of the disease, a coalescence of the blind areas gradually brings about types of ring scotoma. In the regressive stage of this form of choroiditis, perimetric symptoms appear in reverse order. As absorption takes place, a gradual shrinkage of the blind areas breaks up the ring formation, healthy choroid again "breaking through." Areas which were absolute scotomata now become relative, and either finally disappear, or remain blind to one or more colors and become indistinct in character. Perimetry therefore is of inestimable value in prognosis, both in the progressive and regressive stages of luetic choroiditis.

Contraction of the peripheral field for form and colors is rarely observed in choroiditis, but when present it is an indication that the retina—and particularly the axis cylinders and the inner neuron of the retina—have become involved. This is observed in so-called choroiditic atrophy of the nerve or optic atrophy secondary to choroiditis. That marked disturbance in function may occur in choroiditis without ophthalmoscopic evidence is illustrated in a case of partial ring scotoma represented in Figs. 54 to 57. This case occurred in the practice of Dr. Wendell Reber. The patient complained of a defect around central vision of the right eye. The ophthalmoscope did not show any variation from the normal. A perimetric study, however, showed a positive and an absolute scotoma, horseshoe in shape, surrounding the

macular region. Under salvarsan treatment the patient recovered completely. In this case the nutrition of the

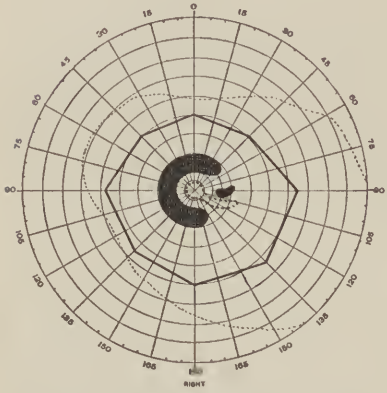


FIG. 54. — December 9, 1913. Form field contracted, blind spot enlarged. Absolute ring scotoma.

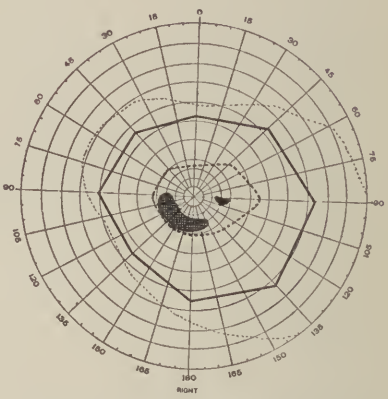


FIG. 55. — December 20, 1913. Blind spot and ring scotoma shrinking under antisyphilitic medication. Ring scotoma absolute.

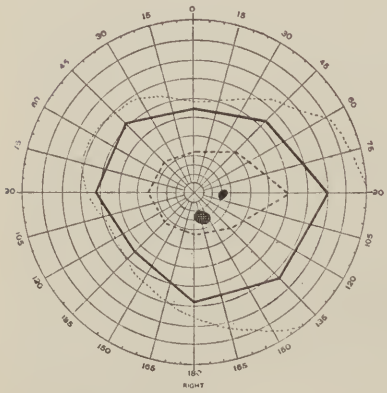


FIG. 56.—December 31, 1913. Form field almost normal. Normal blind spot slightly enlarged. Minute area of the ring scotoma left, still absolute.

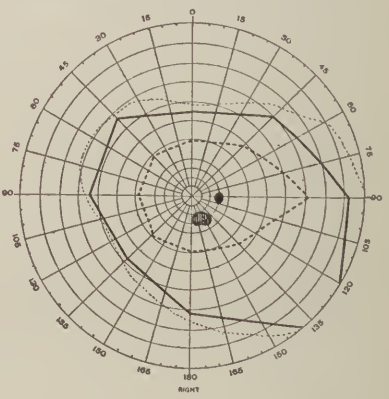


FIG. 57.—January 6, 1914. Form and color fields almost normal. Blind spot of Mariotte about normal. Small relative scotoma—the remains of the ring scotoma.

FIGS. 54–57.—Ring scotoma and syphilitic chorio-retinitis. (Case of Dr. Wendell Reber.)

neuro-epithelium of the retina was disturbed by the syphilitic process.

In all forms of choroiditis, perimetric studies furnish abundant justification for the time and labor spent. Not only is it an aid to diagnosis, but it furnishes the only dependable data upon which a prognosis can be made. Lues and tuberculosis are the acknowledged etiological factors in a large portion of choroidal diseases, and when due to the former, improvement may be looked for under suitable treatment. During the regressive stage, therefore, the progress of the case can be determined more accurately and minutely than it is possible to determine by means of the ophthalmoscope.

NIGHT-BLINDNESS.—Idiopathic nyctalopia, improperly called hemeralopia, is a condition in the production of which both choroid and retina have a share. Night-blindness is a symptom of retinitis pigmentosa, but the idiopathic variety is entirely functional in character and the eye-ground remains normal. It is characterized by anesthesia of the retina, loss of adaptation and diminution in central and peripheral qualitative and quantitative color sense. Pathologically, two factors probably are operative in its production—exposure to strong light and a condition of malnutrition. It occurs especially in soldiers' and sailors' barracks, in overcrowded orphanages, and in schools for children, and, as claimed by some, it is observed in Russia during the Lenten season.

A study of these cases perimetrically shows especially a quantitative loss of color sense, particularly for blue by daylight, but to greater extent in subdued light; contraction of form and color fields, increasing with twilight—and occasional shrinkage of the form field in good daylight. In all these variations from the normal, predominant symptoms are marked contraction of the blue field in good light, increasing under diminished light, and contraction to a less extent of the red and green in twilight. Whatever bearing exposure to excessive light may have on these cases, the dominating etiological factor is that of malnutrition. The choroidal circulation is at fault,

and the retinal anesthesia and loss of adaptation are the result of an altered blood supply to the neuro-epithelial layer of this structure. Constructive treatment, in the form of suitable food and fresh air, effects a cure.

Day-blindness.—Idiopathic hemeralopia, or day-blindness, is a rare symptom which may be found in those who have long been excluded from the light. Hemeralopia has also been observed in certain congenital affections of the optic nerve, in certain forms of amblyopia especially that from tobacco, in retinitis called by Arlt retinitis nyctalopia as pointed out by de Schweinitz, and in the early stages of nuclear cataract. There are no characteristic field changes peculiar to the symptom. The changes observed are those which are due to the underlying cause.

Retinitis.—Inflammation of the retina is primarily an inflammation of the ganglionic cells and their axis cylinders or nerve fibers which make up the optic nerve. It therefore is a disease of the nerve elements proper. It differs from inflammation of the choroid first, because of differences in the distribution of the bloodvessels; and second, because of the peculiar distribution of the nerve fibers to various parts of the retina. The arrangement of the bloodvessels in the choroid tends to the development of foci of disease, whereas the distribution of the *arteria centralis retinæ* tends to diffuse forms of inflammations which may involve the entire retina. The nerve fibers of the retina, as has been pointed out, pass from the optic disc by a long detour to the temporal limits. To the nasal side they are more direct. Some are short, and others are long. An inflammation which begins in the central zone soon spreads to the periphery. In fact a retinitis usually is a general diffuse condition. Characteristically, therefore, a contraction of the field for form and color is more in evidence than scotomatous areas as observed in choroiditis.

Reduction in the blue field usually is commensurate

with that for form, but red and green suffer usually to a greater extent. In diffuse retinitis, therefore, one of the earliest symptoms is narrowing of the form field. On the other hand, the retinitis with a focus of greatest intensity in the central or intermediate zone may show a contraction for red and green out of proportion to that for form, especially when the examination is made in subdued light. Like idiopathic nyctalopia, a narrowing of the red and green field in subdued light may be an early sign of retinitis when both form and color fields are normal in good light. After retinitis becomes well established, the contraction of the green, red, blue and form fields may be proportionately equal, or areas of greater intensity may cause red and green to disappear before form has shown a great degree of contraction.

Scotomata, when present, as a rule are negative in character. A relative scotoma, as the disease progresses, becomes absolute, and scotomatous areas are enlarged both peripherally and centrally. Ring scotomata may make their appearance, especially when retinitis is central or peripapillary, as the case may be. Ring scotomata, however, are not so frequently observed as in disease of the choroid. On the other hand, central scotomata are not unusual occurrences, as the macular region is frequently the seat of focal disease.

In the regressive stage, absolute scotomata become relative, and the central and peripheral zones show evidence of improvement. Green, which may have been lost even in the macular region, may now reappear and the red field becomes enlarged. The peripheral parts of the retina are the last to recover, and complete restoration of function can rarely be looked for in this part of the retina. The form field, as a rule, will remain permanently contracted. In Fig. 60 are recorded the fields of a severe case of luetic chorioretinitis with fairly good recovery. Color fields are approximately normal. The form field in the left eye

shows the greatest amount of contraction. Central vision is good in both eyes.

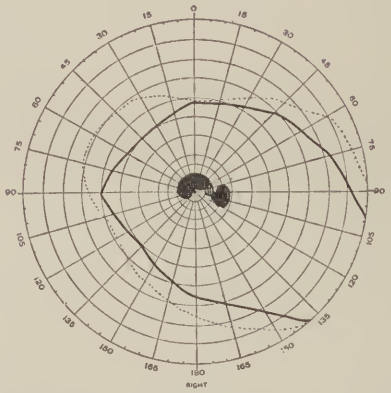


FIG. 58.—Ring scotoma due to peripapillary retinitis.

Forms of retinitis which require special study are luetic, nephritic, diabetic, leukemic, retinitis pigmentosa, solar and electric retinitis.

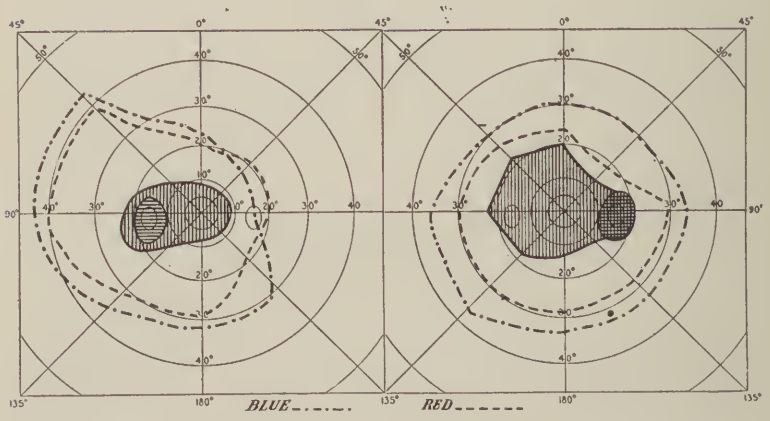


FIG. 59.—Central chorio-retinitis. Enlarged blind spot of Mariotte. Form fields normal. Green field totally lost.

Syphilitic Retinitis.—This infection is carried by the blood stream and therefore advances along the bloodvessel supply. Foci of disease of great intensity

are apt to be present along with diffuse retinitis. The choroid is likewise invaded, and the symptoms, as a rule, form a composite picture of chorio-retinal disturbance. Moreover, the optic nerve itself usually shares in the inflammation. In these cases symptoms of inflammation of the inner neuron may predominate. Contraction of form and color fields is in evidence early. In the course of a few days central vision may be reduced to light perception. If the process is central, various types of scotomata develop. Indistinct scotomata are frequently noted, and as the disease progresses, relative, and finally absolute scotomata appear.

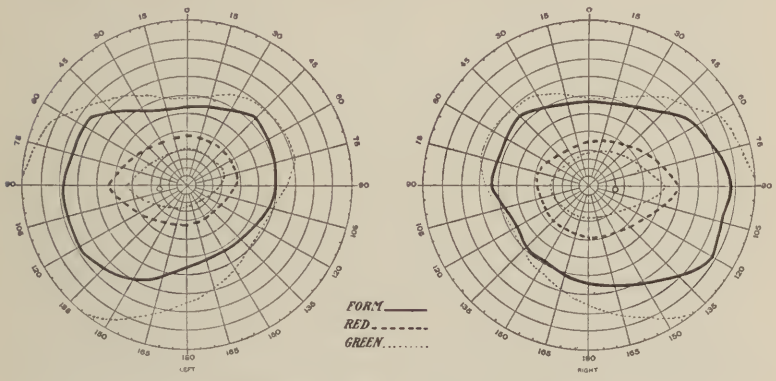


FIG. 60.—Luetic chorio-retinitis. Recovery.

At times they are central, in other cases multiple, with formation of an irregular ring scotoma. They are usually negative in character because of the greater involvement of the nerve elements, but the positive blind area is also seen. In fact, no type of retinitis is more varied in its perimetric symptomatology than that of lues. As prognosis is more favorable in this type of retinal inflammation than in any other form of retinitis, perimetric studies are particularly varied and valuable in the regressive stage of the disease. In fact, in so many instances the onset is so rapid that field studies are not of much value in the early stages of disease. Recovery is rarely complete, espe-

cially in the extreme peripheral parts of the retina; and when carefully studied, indistinct types of scotomata may be found, even in the central zone.

Nephritic Retinitis. — Nephritic retinitis, inaptly called by the older writers "albuminuric retinitis," is a form of retinal disease in which toxins and arterial hypertension are the chief etiological factors. It varies in degree from a mild, localized or diffused edema of the retina, to a neuro-retinitis at times hemorrhagic in type, and a papilledema which to all appearances resembles the choked disc of brain tumor. The so-called albuminuric retinitis is only one of the types of eye-ground changes observed in chronic interstitial nephritis. In the early stages a hazy retina may be observed together with a loss of light streaks on the retinal vessels. Occasionally, even at this early stage, small areas of marked edema may be observed, especially in the macular region. Perimetrically, it is characteristic of this condition to find at the onset of eye complications, in this mild form, a beginning contraction of both form and color fields. The edematous areas in the macular region are recognized by the patient as indistinct scotomata, often positive in character. If hemorrhages appear of sufficient size and density, relative and absolute scotomata are found to correspond to the hemorrhagic areas. More often, hemorrhages, even of dense character, are apt to produce indistinct scotomata. The so-called albuminuric retinitis stage is characterized by marked contraction for form and colors, and scotomatous areas which coincide with the atrophic areas, which have given this form of retinitis its name. The enlargement of the normal blind spot of Mariotte marks the beginning of a swelling of the nerve head, and irregular scotomata in the central zone are the evidence of changes in the nerve head and retina incident to papillitis or choked disc, namely, hemorrhage, atrophy, and detachment of the retina.

Perimetric studies in nephritis of pregnancy differ

very little from those described for chronic interstitial nephritis. The toxic element is probably more in evidence than that of hypertension. The perimetric

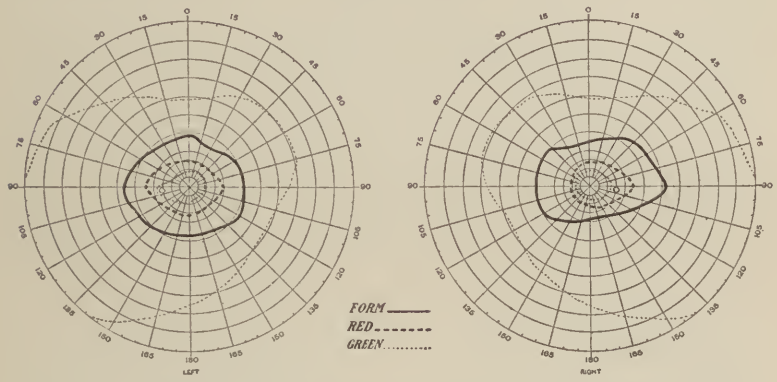


FIG. 61.—A typical field of chronic interstitial nephritis. Blood-pressure 200 mm. Hg.

findings therefore are the result more directly of disturbed nutrition than of edema, and contraction of form and color fields is quite common. When eye

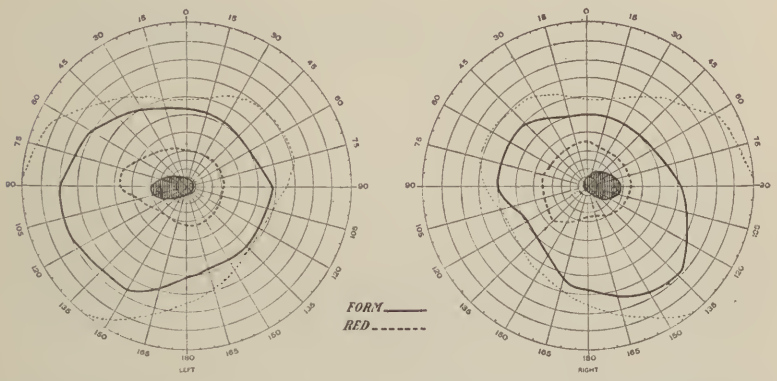


FIG. 62.—Chronic interstitial nephritis. Indistinct central scotoma due to edema and partial detachment. Scotomata positive.

changes are marked, the perimetric changes become those which are noted in chronic interstitial nephritis. However, in this form of nephritis recovery may

become complete and fields may become relatively normal.

The perimetric characteristics of nephritic retinitis, therefore, are: (1) Contraction of form and color fields, even in the early stages of the disease; (2) indistinct scotomata which later may become relative or absolute. These scotomata may occur in any part of the field, but most characteristically develop in and about the macula; (3) enlargement of Mariotte's blind spot.

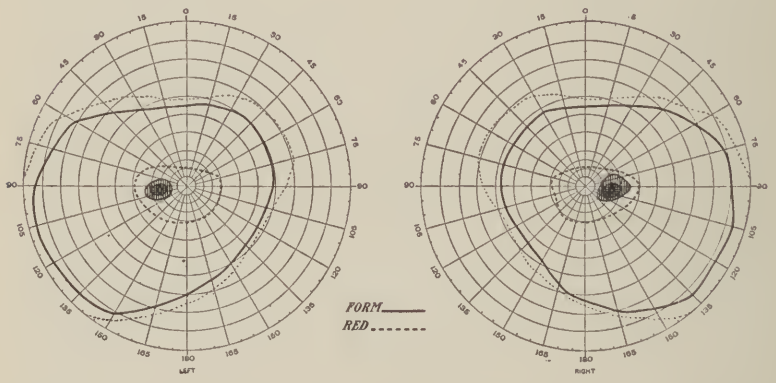


FIG. 63.—Neuro-retinitis in the eighth month of pregnancy. Absolute enlargement of the normal blind spot surrounded by a relative scotoma for red. Recovery. (Case of Dr. Reber.)

Diabetic Retinitis.—In diabetic retinitis, perimetric changes similar to those of chronic Bright's disease are observed, but milder in character. The contraction of form and color fields is present, but not to so great an extent. As the atrophic areas are usually minute and scattered, scotomatous areas are not so frequently observed. They are, however, present in some cases, and usually are situated in the macular region. As arterial hypertension is not so great, hemorrhagic retinitis is less frequently observed, and when present the hemorrhagic areas are smaller and less apt to give rise to scotomata of sufficient size to be recognized. It is well to remember, however, that chronic diabetes,

as a rule, may eventually be accompanied by chronic interstitial nephritis, and the perimetric findings may become as marked as in a case of chronic Bright's disease.

Leukemic Retinitis.—In leukemia, pernicious anemia, and other blood dyscrasiæ, a form of retinitis is observed which is characterized by large and massive hemorrhages. Occasionally an optic neuritis may be present. The process as a rule is a rapid one, and therefore the eye symptoms are due largely to hemorrhagic retinitis. Positive, indistinct, irregular, scotomatous areas are observed by the patient, and the perimetric findings

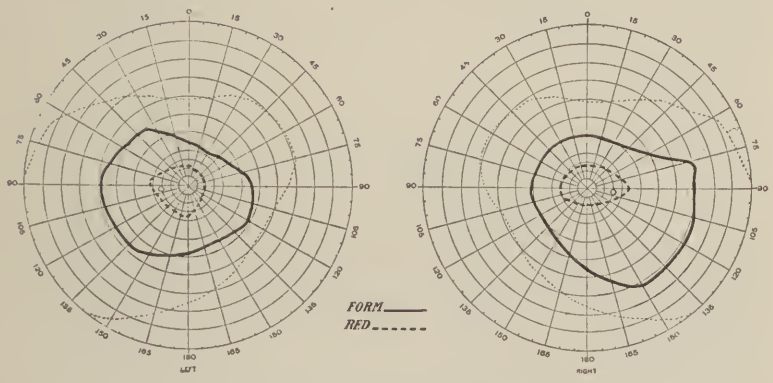


FIG. 64.—Fields in a case of Hodgkin's disease.

correspond to the hemorrhagic areas observed. If neuro-retinitis is present and the disease is prolonged, contraction of form and color fields may be observed. Vision, however, may be so rapidly lost in this type of disease that perimetric studies are not of great value.

Hodgkin's Disease.—The author had the opportunity of studying a neuro-retinitis in a well-marked case of Hodgkin's disease. The eye-ground resembled the eye-ground frequently observed in advanced tuberculosis, namely, a blurred disc, the retina hazy throughout, engorgement of the retinal veins, some tortuosity of the arteries, and total absence of the light streaks

on vessels. Fields in this case show a contraction for form and color.

Solar and Electric Retinitis.—Exposure of an unprotected eye to a solar eclipse sometimes produces a form of retinitis which is characterized by a positive central or paracentral scotoma which may be temporary in character, but more often permanent. In the zone immediately surrounding this scotoma, marked changes in color fields may be noted which take the

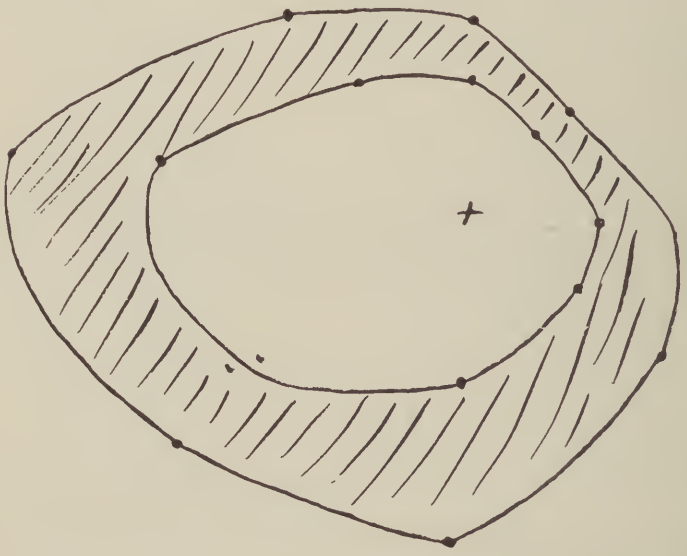


FIG. 65.—Entoptic study of a ring scotoma due to looking into a furnace fire. (Case of Dr. J. Claiborne.) (Annals of Ophthalmology.)

form of indistinct, relative or absolute scotomata. These scotomata may disappear, or may remain permanently. Contraction of the form field is also observed if the exposure to the sun's rays has been prolonged. A similar condition is observed in sudden exposure to strong electric-light explosion. Marked atrophy of the retina and of the optic nerve may result, and the damage frequently is permanent. Positive central scotomata, with marked disturbance for colors over large central areas, and contraction

of form and color fields, are the usual evidences on the perimeter.

Jess[1] reports 26 cases of ring scotomata out of a total of 36 cases studied. In most instances the ring was

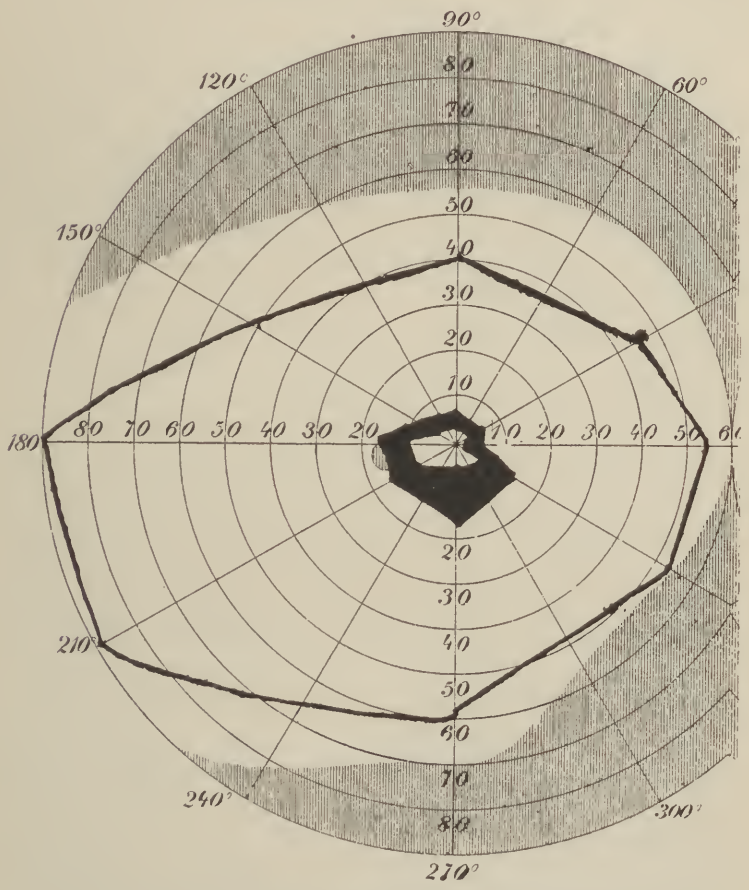


FIG. 66.—Perimetric study of Dr. Claiborne's case of ring scotoma. (Annals of Ophthalmology.)

incomplete, varied from 10 to 25 degrees in width, and usually was found between the 20th and 50th degrees. Speleers[2] found a similar condition in 6 cases out of

[1] Arch. f. Augenh., vol. 74, p. 78.

[2] Klin. Monatsbl. f. Augenh., November, 1912, p. 636.

13 studied, and in 11 cases he noted an enlargement of the blind spot of Mariotte.

It is difficult to explain the origin of ring scotoma in solar retinitis. In the light of our present knowledge, however, the injury may be regarded as thermic. In snow-blindness, the ultra-violet rays may play the important role.

An unusual case of ring scotoma was reported by Dr. J. Herbert Claiborne in the *Annals of Ophthalmology*, January, 1915. The scotoma was due to looking into a furnace fire for a long period. Fig. 65 represents the drawing of the scotoma by the patient, by entoptic study, and Fig. 66 the field of the patient taken on the perimeter.

Retinitis Pigmentosa.—Retinitis pigmentosa is an atrophic or sclerosing process which involves the choroid and retina. By some it is believed the choroid is the first to suffer; whereas, others believe the sclerosis develops in the choroid and retina about the same time. It is, as a rule, hereditary, recurring frequently in several members of the family, and in a large percentage of the cases in children of consanguineous marriages. Clinically, it is characterized by an early deposit of pigment of peculiar arrangement about the equator of the eyeball, by atrophy of the optic nerve with fairly distinct nerve head, a marked contraction of both retinal arteries and veins, and a visible choroidal circulation which becomes more plainly visible as absorption of pigment of the neuro-epithelial layer progresses. The symptom of which the patient complains is gradual loss of vision, which is especially marked in twilight. Patients whose orientation in daylight is good find it difficult to grope their way in the dark. This night-blindness, or nyctalopia, is present in most cases, but occasionally may be found absent.

Perimetrically, the characteristic symptoms are: (1) A progressive and rapid contraction of the form field, sometimes irregular, but usually concentric;

(2) preservation of central vision for form and colors long after peripheral vision has become extensively lost; (3) ring scotomata, in the earliest stages of disease; (4) the absence of central defects until the

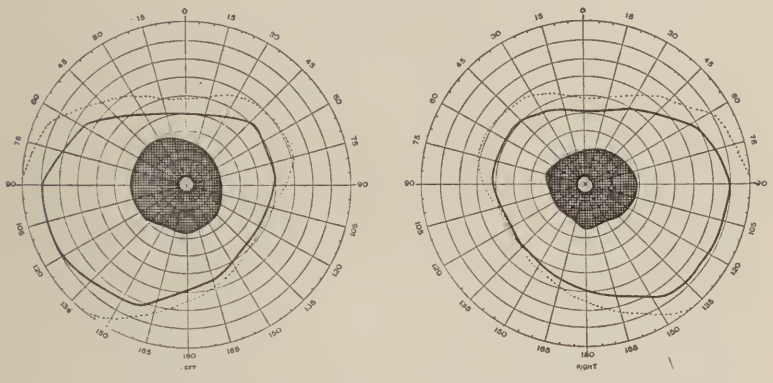


FIG. 67.—Retinitis pigmentosa.

progressive loss of the form field encroaches upon central vision. Most of those who have made careful studies of the condition agree that progressive con-

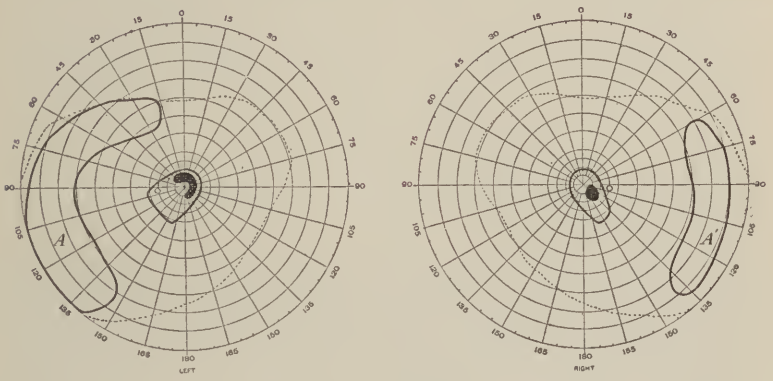


FIG. 68.—Retinitis pigmentosa. (Case of Dr. Wendell Reber.)

traction of the form field is the earliest and most characteristic perimetric finding. Köllner, however, claims the broad ring scotoma is the earliest perimetric symptom. Most investigators believe the choroid

suffers first, and the observations of Köllner would tend to confirm this view. As a matter of fact, however, few cases are studied sufficiently early to confirm Köllner's observation, but clinically, a contracted form field is usually the first perimetric symptom to be noted. In many cases, the contraction takes place irregularly. It is interesting to note that the red field may extend well up to the limits of the form field. A larger number of cases show, on the other hand, the concentric contraction of form and color fields, especially when the contraction is marked, as in Fig. 68.

The above field illustrates well the second characteristic of retinitis pigmentosa, namely, a preservation of central vision out of proportion to the contraction of the form field. Exceptions to this symptom are occasionally noted when the process begins in the central zone rather than in the equator of the eyeball. Nearly all of the fields taken in this disease exhibit color fields which are as extensive, or nearly so, as the form field. In Shoemaker's study of 17 cases he was able to demonstrate color sensibility in the macula in most of his cases with an object as small as 2 mm. in diameter. The macular sensibility in most instances is preserved until late, not only for colors, but central vision remains fair even when orientation becomes difficult because of contracted fields. Numerous instances are recorded in which the patient was able to pick out individual letters in print when orientation was completely gone.

In Shoemaker's 17 cases, he was unable to find an instance of ring scotoma. He concludes, therefore, that if present at all, it is a rather rare phenomenon. Theoretically, if our suspicion of early choroidal involvement is correct, the ring scotoma should be of frequent occurrence. Practically, however, it is infrequently observed, and this notwithstanding the reference made to it by nearly every writer on the subject. Possibly this discrepancy can be explained by the rather late studies which are usually made in this disease.

Finally, it is generally conceded that central vision is intact, or at least present, late in the disease; central scotomata are observed only in those anomalous cases in which the sclerosing process affects primarily the macular region and the peripheral involvement becomes secondary. Cases of this type appear in literature. Central vision, as a rule, finally disappears and the patient becomes blind. A few cases, however, show a tendency to arrest of the process after the fields have become markedly contracted, and in a few instances fields have been preserved even in late adult life.

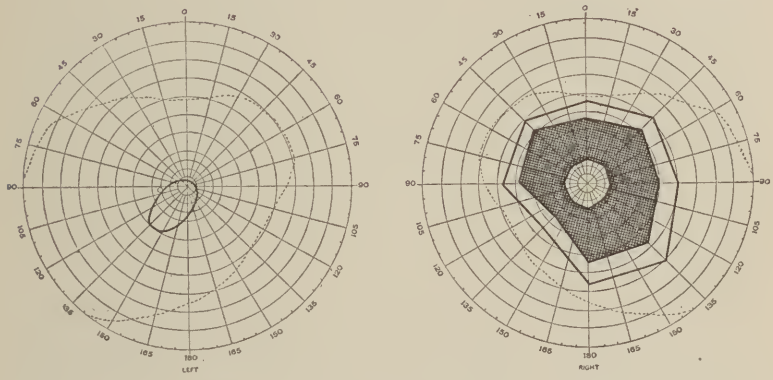


FIG. 69.—Retinitis pigmentosa of luetic origin. (Patient in service of Dr. Reber.)

The luetic origin of a few cases has been conceded by some, but denied by others. In Fig. 69 is recorded a field of retinitis pigmentosa in which lues probably is the cause. The eye-ground has the appearance of the typical retinitis pigmentosa, hereditary in origin. In addition, however, the nerve head is quite indistinct, there is a perivasculitis present, and there are fine opacities in the posterior part of the vitreous body. Furthermore, his sight began to trouble him at about forty years of age. He admitted the history of a chancre and he had a positive Wassermann. The case, I believe, is one of luetic retinitis pigmentosa.

Detachment of the Retina.—Perimetric studies in retinal detachment are of most value in the predetachment period and in the stage of recovery, if reattachment takes place. In a retinal detachment which is plainly visible by the ophthalmoscope and by the patient, a field defect for form and color will be found corresponding to the detached area, recognized by the patient as a positive scotoma and by the physician as a gray elevated area in which light reflex is absent. When complete, the detachment gives rise to an absolute scotoma. In its earlier stages, however, when the patient is conscious only of the cloudy area in his field, an indistinct scotomatous area will be detected in which possibly only qualitative color changes may be observed. Blue-blindness, or at least a qualitative change in blue, is one of the earliest symptoms at this stage of the process. After the retina has become separated and an absolute scotoma appears, there will be found an indistinct scotomatous area surrounding the absolute scotoma in which these qualitative changes will appear.

In disseminated choroiditis, high myopia, retinal edema of chronic interstitial nephritis, or other conditions in which retinal detachment may appear, perimetric studies are of great value. Lohmann has called attention to green vision of patients for weeks before detachment appeared, the same symptom being present in one case a year after reattachment. He quotes Köllner's observation, especially in one patient who saw blue hyacinths as green in the affected eye. Other patients will see green spots in their visual field. Blue-yellow-blindness may therefore be regarded as an early symptom of retinal detachment. Blue may appear as green or black, and yellow as white.

When reattachment takes place, as in the milder forms of the disease, the form field may again be restored. Qualitative changes in color, however, are more or less permanent, even in mild cases. In Fig. 70 is represented a form of retinal detachment

which occurred in chronic interstitial nephritis. Subjectively, the patient complained of an unevenness of the floor, and a sensation of wet spots on the floor and street. Perimetrically, he showed an indistinct scotoma for form and marked confusion for colors in the macular region. A white edematous area was recognized in the macula by the ophthalmoscope, in addition to other phenomena of chronic Bright's. Recovery was good, but qualitative color changes remained in the region of the detachment.

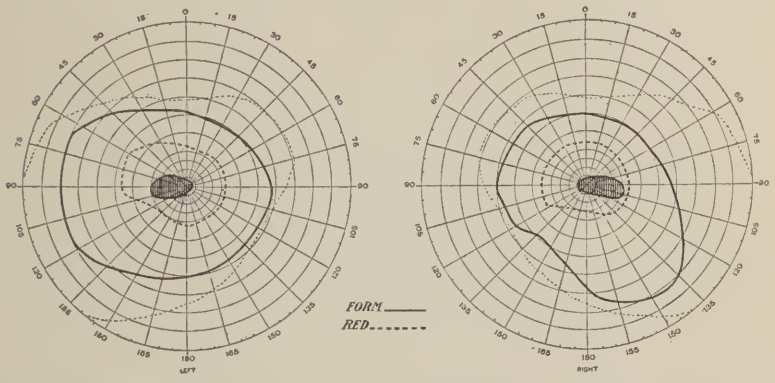


FIG. 70.—Partial detachment of retina in a case of chronic interstitial nephritis.

Detachment may occur in any part of the retina. Its location will be determined by the cause of the detachment. Its tendency, however, is downward, unless caused by a neoplasm, when the detachment will be in the direction of the growth. If the detached retina is in the upper part of the eye, the defect will appear in the lower part of the field, and *vice versa*. The line of development will be down, the upper part often reattaching itself as detachment increases downward. In malignant forms of detachment, when the vitreous body shrinks, the condition grows progressively worse until the retina is attached only at the ora serrata and the posterior pole of the eye, and vision becomes entirely lost. It is possible in many instances to follow

a detachment when it is advancing by means of the ophthalmoscope, and the patient, if intelligent, can note the progress of the disease entoptically. The perimeter, however, gives one more accurate knowledge; it is especially of value in determining the probable arrest of the process.

Commotio Retinæ.—The vulnerability of the macula is observed in *commotio retinæ.* In direct blows on the eyeball, injury is liable to show itself at a point directly opposite the point of contact, namely, at the macula (contracoup). The patient complains of an area of cloudiness which may center in the macula or

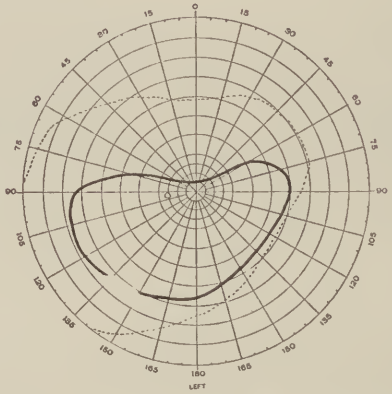


FIG. 71.—Retinal detachment. (Reber.)

may surround central vision. The usual ophthalmoscopical symptoms will be observed in proportion to the severity of the injury. A positive scotoma may be observed centrally, or, more frequently, a ring scotoma may be formed. Lohmann has endeavored to explain this ring scotoma by the firm attachment of the tunics of the eye to the optic nerve, thereby preventing the macular region from being wrenched from its attachments. The force of the blow is distributed around the papillo-macular region. The explanation appeals to one as being entirely rational and plausible, and it

will explain the formation of a ring scotoma in this disease when visual acuity remains normal. It is

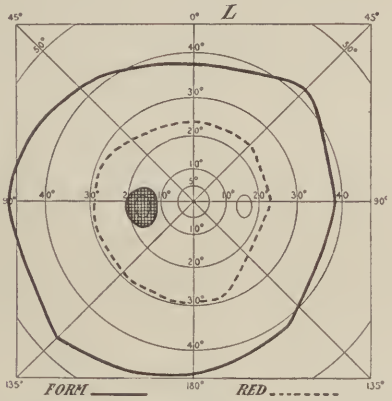


FIG. 72.—Injury of optic nerve from a blow on the eyeball. Enlarged blind spot of Mariotte.

reasonable to expect a central defect in direct blows upon the eyeball. The greater activity of the macular

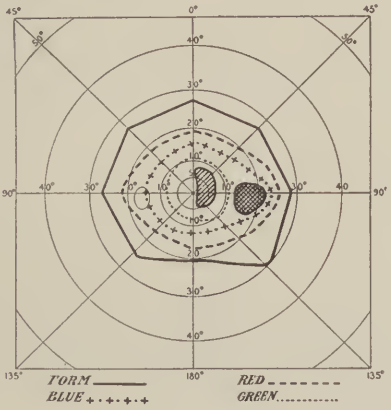


FIG. 73.—Commotio retinæ. Enlarged blind spot of Mariotte. Indistinct paracentral scotoma. Form and color fields much contracted.

region is made possible partly by the greater activity of the choroid underlying it. Injury to the choroidal

circulation, therefore, is apt to be followed by retinal changes. Notwithstanding the possible influence of the firm attachment to the optic nerve, visual acuity often suffers. The relative or absolute character of the scotoma, whether central or ring, and the extent of the blind area, will depend much more upon the severity of the blow. Recovery may be good and complete, but in severe forms there may be not only permanent central defects, but the peripheral area of the retina may show disturbance in the contraction of form and color fields (see Fig. 73).

Traumatic Anesthesia of the Retina.—Traumatic anesthesia of the retina is the name given by Leber to a group of symptoms following injury to the globe without discoverable ophthalmoscopic changes. It forms a symptom group which really belongs under the heading of Commotio Retinæ or Traumatic Retinal Edema. Clinically, it differs only from the latter in the absence of visible signs other than disturbed central vision. The perimetric findings agree with those which have just been described under Commotio Retinæ. The injury in these cases seems to cause a rather diffuse disturbance of the retina, which may result in central and paracentral defects and considerable contraction of the form field. Perimetric changes may remain permanently, or they may disappear in a few days.

Traumatic Hole in the Macula.—In this same group one might include this rather rare phenomenon which may follow a contusion of the eyeball. A depression may be observed in the macula of a deep red color with clear-cut edges. This may be only evidence of injury, in which case a small scotoma will be found centrally or paracentrally situated.

Rupture of the Choroid or Retina.—Rupture of the choroid or retina may be found associated with hole in the macula. One or more white lines may be found radiating from the macular hole, with or without hemor-

rhages along their course. A break in the choroidal circulation will be followed by retinal changes in the same area, and permanent scotomatous areas will be found to correspond to the atrophy of the choroid and retina which follows. The choroid may alone be found ruptured, but retinal atrophy must necessarily follow because of disturbance of its nutrition. In the more aggravated cases, retinal detachment may be the final outcome, and corresponding perimetric symptoms will therefore be elicited.

Embolism and Thrombosis of the Central Artery of the Retina.—Three types of occlusion of the central vessels of the retina are observed: Embolism, thrombosis, and occlusion by endarteritis proliferans. Clinically, it is not always possible to differentiate between these types of occlusion, but the ultimate effect upon the retina is probably the same. Perimetric studies in these conditions are of little value in some cases, but of great value in others. The onset in embolism is so sudden that vision is lost throughout the retina suddenly and blindness is the result. The process in thrombosis and in endarteritis is more gradual, but also complete in many instances. More frequently one or more branches of the central artery are affected, and disturbance of vision therefore is only partial. The part of the retina supplied by the occluded vessels will show total absence of form and color fields, the balance of the field remaining intact.

Fig. 74 is the field of a patient who, at eighteen years of age, suffered from thrombosis of the inferior branch of the central artery of the retina. The inferior retinal vessels are reduced one-half, the inferior part of the disc is atrophic, and the lower half of the retina shows the usual atrophic pallor. Central vision is not disturbed. It was 6/4 ten years after the thrombosis occurred. Even in the seeing half of the field one notes the peripheral part of the retina has suffered. The colors have also undergone a moderate degree of contraction.

Along the upper border of the field, color fields coincide with that for form. The presence of cilio-retinal vessels,

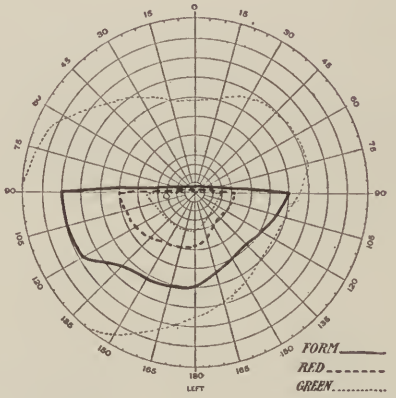


FIG. 74.—Thrombosis of inferior branch of central artery of retina of seventeen years' standing.

which occur in about 16 per cent, sometimes saves central vision. A slit-like field, running horizontally,

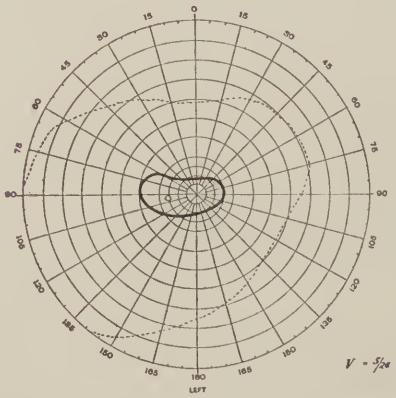


FIG. 75.—Embolism of central artery of retina. Cilio-retinal vessels intact. (Reber.)

will be preserved in the macular region, even though the central artery is completely occluded, if the cilio-

retinal artery is present. The extent of the preserved field will depend upon the size and the extent of the distribution of the cilio-retinal vessels. In exceptional instances these vessels are unusually large and have a rather wide distribution. Under these circumstances, a considerable part of the perimacular field will be preserved.

If blindness from occlusion of the central artery of the retina is complete and remains so for several days, even partial recovery is not likely to occur. In rare instances, treatment is of some avail and sight may be

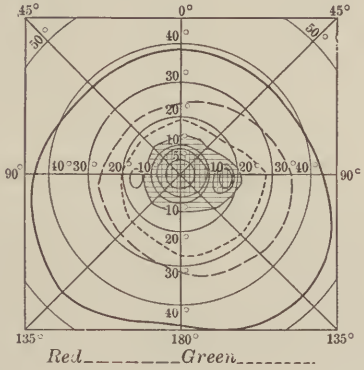


FIG. 76.—Central scotoma with peripheral contraction of form and colors, caused by an occlusion of the artery supplying the macular region.

recovered. The completeness and duration of the occlusion will determine the extent of the recovery. In arteriosclerosis, angiospasm may be a cause of this phenomenon, and both clinical and perimetric signs of arteriosclerosis will be present. Recurrent attacks of angiospasm, therefore, with contraction of form and color fields which persist between the spasmodic seizures, are of bad omen. Such attacks should be looked upon as danger signs of great moment. Embolism or occlusion of the macular branch of the central artery of the retina is rather rare. Fig. 76 is

the field of a case in point under the author's care for several years. The patient was a soldier boy who, several months after he was mustered out, suddenly lost the sight in his right eye. Vision was totally absent in his central field and much disturbed in his peripheral field. When first observed immediately after the onset, the posterior pole of the eye showed a uniform pale indistinct area in which the disc was scarcely visible, and which gradually disappeared into the peripheral retina which was not markedly changed. Fields at this time showed a large blind area with contraction of his peripheral limits. After two months, a well marked sharply outlined atrophic area was visible in the macular region, surrounded by fairly healthy retina and the collapsed macular artery was visible as a faint white line. The Wassermann in this case was positive.

If recovery from occlusion of the central artery or its branches takes place, restoration of the retinal function may be complete, or the field may be disturbed in whole or in part. The peripheral parts of the retina may show contraction of form and color fields and scotomatous areas may be found. Such changes will be similar to those found in disease of the ganglionic and axis cylinder layers—the red-green changes being most marked and persistent.

Thrombosis of Retinal Veins.—Thrombosis of the retinal veins, clinically, presents a picture which differs markedly from that of occlusion of the central artery. Insofar as the ultimate outcome is concerned, however, it differs but little. It is a destructive process, and blindness as a rule is the sequel. The rapidly developing edema of the nerve head and retina, associated with large hemorrhages and exudate, quickly destroys the eyesight. Perimetric studies are not essential in diagnosis, and of little or no value in prognosis. Prognosis is usually bad. Thrombosis of a branch gives rise to an indistinct relative or absolute scotom-

atous area, the extent of which will depend upon the location of the thrombosis.

Posthemorrhagic Amblyopia.—These hemorrhages may occur from the stomach, lungs, uterus, venesection, etc. The blindness and defects in visual fields are now recognized as the result of degeneration of the ganglionic and, secondarily, of the nerve-fiber layer of the retina, due to ischemia. Blindness may follow a single hemorrhage, or repeated hemorrhages. It may develop during the course of the hemorrhage, or be complete only after a period of several months. The prognosis is not favorable, as high as 50 per cent remaining unimproved, while a small number are improved, and possibly 10 to 15 per cent recover completely. Perimetric findings vary greatly. There may be concentric contraction for form and color, this contraction continuing to the extent of 15 degrees, or remaining *in statu quo*, or blindness may supervene. In other instances sector-like defects or scotomatous areas—relative or absolute, central or paracentral in character—may develop. In some instances central vision may be preserved while in others it suffers much reduction. F. Terrien[1], reported 2 cases in which there was loss of both lower fields. In explaining this peculiar type of field, which has been observed frequently, he calls attention to the fact that amaurosis does not usually occur in traumatic cases, but in those who suffer from general disease. The loss of blood in itself is not the cause of the blindness, in his judgment, otherwise the blindness should develop immediately rather than late. The ischemia, however, allows the action of toxins, which are present in the patient, to play the important role. The upper retina suffers most from a mechanical standpoint when the blood-pressure is lowered.

Magitot[2] found the pressure very low, so low that the blood stream could hardly reach the retinal arteries.

[1] Arch. d'Ophtal., May, 1921.

[2] Ann. d'Ocul., November, 1910, vol. 155.

He also found the upper fields preserved better than the lower halves and offers the suggestion that a postural position, even that of Trendelenburg as a prophylactic measure worth trying. Like the amblyopia of quinine poisoning, the optic atrophy from remote hemorrhages is due first to ischemia of the ganglionic or third neuron, the destruction or death of these ganglionic cells being followed by atrophy of their axis cylinders which go to make up the optic nerve.

Coloboma of Choroid and Retina.—Coloboma of the choroid and retina is an associated condition, and as a rule is bilateral. As the retina is either totally absent or in an atrophic state, a scotomatous field defect is found corresponding to the area observed with the ophthalmoscope. The scotoma, however, as a rule is relatively smaller than the coloboma, and in the periphery of the scotoma may be found an indistinct scotomatous area. The rod and cone elements are present in this area, but not so active as in other parts of the retina, and a qualitative and quantitative loss of light and color sense can be made out. The scotoma proper may be relative or absolute, but usually is negative in character. Instead of total absence of light sense in the colobomatous area, modified light sense may be preserved, as demonstrated by Schmidt-Rimpler and others. The presence of color sense has also been demonstrated in colobomatous areas. This would argue for the preservation of the retina in a modified form in some colobomata. As most colobomata extend close to the disc, the field defect observed may be continuous with the enlargement of the normal blind spot of Mariotte. This is especially true when the coloboma includes the entrance of the optic nerve.

Coloboma of the Optic Nerve.—Coloboma of the optic nerve is rarely found as a distinct and separate condition but usually is associated with coloboma of the choroid

and retina. It does occur, however, occasionally—not only in the form of Fuch's coloboma, but in a total coloboma of the optic nerve without much involvement of the choroid and retina in immediate juxtaposition. Coloboma, however, is a congenital defect, and it therefore is usually found associated with other congenital anomalies. It not infrequently happens in this form of coloboma as in others, that we not only find a negative scotoma, relative or absolute, but other field defects as well. Peripheral changes are frequently observed. Concentric, or more frequently irregular, contraction of both form and color fields have been recorded.

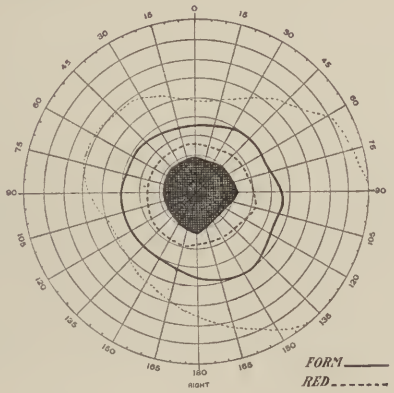


FIG. 77.—Coloboma of optic nerve and posterior pole of eyeball.

Coloboma of the Macula.—Coloboma of the macula occurs as an isolated condition, or a part of a more extensive colobomatous area. Under any condition of macular coloboma, a central scotoma will be found; and in those cases in which the coloboma is extensive, involving a large portion of the posterior part of the eye, fields may be found so defective as to be difficult to take. In Fig. 77 is recorded the field of a patient suffering from unilateral coloboma which includes the optic nerve and macula. In the center of the field

is an absolute scotoma which corresponds to the colobomatous area as observed by the ophthalmoscope. While useful peripheral vision is preserved, there is shrinkage of both form and color fields.

Medullated Nerve Fibers.—Medullated nerve fibers give rise to field defects directly in proportion to their number and extent. These medullated nerve fibers are usually found above and below and in the direction of the distribution of the nerve fibers. They are opaque, and therefore the perimetric defect observed is enlargement of the normal blind spot in an upward and downward direction. As the medullated fibers naturally follow the distribution of the fibers above and below the macula toward the raphé, a comet-shaped scotoma may be observed corresponding to the distribution of the opaque fibers. In this respect, the scotoma resembles the Bjerrum sign observed in glaucoma, not only in its extension from the blind spot of Mariotte, but in being detached from the blind spot as the fibers are sometimes found. The scotoma, however, is only indistinct or relative; never absolute. The degree of the color defect will be in direct proportion to the density and extent of the medullated fibers. (See Plate V.)

Wounds of the Retina.—In wounds of the retina a varied perimetric picture will be found, as might be expected, the defects being influenced by the character and extent of the wound. The nerve fibers are distributed radially from the optic disc to the periphery excepting in the macular region, where they become somewhat deflected from their course to supply the peripheral region beyond the macula. A punctured or incised wound of the sclera, choroid and retina, therefore, if made in the direction of the nerve fibers, may not produce other field defects than a small coloboma corresponding to the size and shape of the wound, providing the choroid and retina have not been loosened from their attachment. When, however,

a wound is made through the sclera, at right angles to the radiations of the retinal nerve fibers, an atrophic area will eventually be found extending from the line of the wound to the extreme periphery of the ora serrata, more or less quadrangular in shape, as the retinal nerve fibers severed must necessarily undergo degeneration throughout the extent of their distribution from the site of the wound. It will rarely happen, however, that an incised wound of the sclera, choroid and retina can be made without more or less early and late detachment of the retina for some distance beyond the immediate neighborhood of the wound. A scotomatous area, therefore, may be found extending from a point in the field corresponding to the location of the wound in the retina to the extreme periphery—or what is more frequently the case, the defect may extend beyond the borders, as the extent of the detachment will determine. Perimetric findings may be out of proportion to the apparent size and extent of the wound, and will depend upon the nature and degree of the trauma inflicted.

DISEASES OF THE PAPILLA OR INTRAOCULAR PART OF THE OPTIC NERVE.

Anatomically, the nerve head is distinguished from the nerve proper by the absence of medullated sheaths, and for convenience in discussion this part of the nerve will be separated from the optic nerve proper. In this group will be included papillitis, choked disc and glaucoma.

PAPILLEDEMA AND PAPILLITIS.—Papilledema or choked disc primarily is a condition of congestion of the nerve head due to a mechanical cause, namely increased intracranial pressure. As a rule it should be regarded as a distinct and separate entity. In most instances an inflammation or papillitis will follow and

the two conditions may be found in the same patient. Papilledema is an early phenomenon and when pure in type there are unmistakable signs which clearly stamp it as a simple swelling of the nerve head. The height of the swelling and the rather definite outlines, over which the vessels can be followed in their descent to the retina of a lower level, are signs which cannot be confounded with the appearance of a papillitis. In the latter the limits are not well marked, but gradually merge into the surrounding retina which also shares in the pathology. Arteries and veins are engorged and tortuous, and become lost in the blurred and hemorrhagic area which occupies the seat of the nerve and its environs. Swelling may be in evidence but it is moderate in degree and extends well beyond the nerve.

If we accept the mechanical theory as to the etiology of choked disc there may be a time in its development when only the distal, or intraocular end of the optic nerve is involved. A papillitis is apt to follow, and ascending or descending atrophy will eventually supervene. When, therefore, it exists as a separate entity, what may be regarded as rather characteristic of the condition is an enlargement of the normal blind spot. Instead of an absolute enlargement, an indistinct scotomatous area may be found surrounding a blind spot of normal size, in which both color and form can be determined but with uncertainty. If the swelling increases and persists, the more vulnerable papillomacular bundle of nerve fibers may lose their integrity, and a central relative, and later absolute, scotoma may appear. Union of the enlarged blind spot and the central scotoma will give rise to a cæco-central scotoma. Active inflammation of the optic nerve, associated with choked disc, brings about peripheral changes in the field, a concentric contraction, or more often sector-like defects of both form and color fields. In fact, the presence of changes in the peripheral fields early in the history of the case is evidence of optic nerve

inflammation rather than mechanical swelling of the disc.

In the acute congestive stage, perimetric symptoms directly referable to the swollen nerve head will be largely confined to the region of the normal blind spot and macula. Continued engorgement, however, is necessarily followed by atrophy on account of the continued pressure under which the nerve fibers are held. Therefore, at the height of the choked disc, or in the regressive stage, peripheral form and color changes make their appearance. These changes consist in concentric contraction or sector-like defects of form and color fields, and in rather rapid loss of the nasal fields—according to Cushing and Walker.[1] All these perimetric findings have been confirmed by numerous investigators. They should, however, be recorded as the result, not so much of the papilledema *per se*, but as indicating damage to the other parts of the optic nerve, and possibly also in part of psychic origin, as exemplified in reversal of the color fields. When reversal of color fields occurs as a symptom of brain tumor, one must not lose sight of the fact that hysteria is not infrequently an associated condition in patients suffering from brain tumor. Reversal of color fields is typically observed in hysteria, and this form of perimetric change should be looked upon as of psychic origin. Against the organic origin of this phenomenon is the fact that it has been observed in neoplasm of various parts of the brain. It is not peculiar to disease of any particular area.

Contraction of form and color fields, whether concentric or sector-like, is usually a late phenomenon and indicates nerve-fiber degeneration. Equally interesting is the rather rapid loss of the nasal field, or so-called nasal hemianopsia referred to by Cushing and Walker in the choked disc of brain tumor. The

[1] Archives of Ophthalmology, November, 1912.

method of development of this phenomenon has been explained by these authors as a pressing out of the chiasm by the distention of the third ventricle which may cause the sides of the chiasm to press against the carotid arteries even to the extent of an indentation of the chiasm. To this, in part, is attributed the symmetric disturbance of the nasal fields so often observed in brain tumor. If this theory is correct, it should be equally true that a force sufficient to crowd the optic nerve against the carotid arteries would likewise bring about types of altitudinal hemianopsia in forcing the chiasm down upon the sphenoid. In overcrowding of the fibers in the optic nerve head, such as occurs in choked disc and in the overstretching in glaucoma, the atrophy which necessarily follows will make its appearance first in the nasal field because of the peculiar distribution and anatomical arrangement of the retinal nerve fibers. It has been pointed out elsewhere that because of the eccentric location of the disc and the direct route of the macular bundle of nerve fibers, the temporal distribution of the optic nerve is accomplished by a longer and more circuitous route than the direct radiations of the nasal retina. The temporal retina is the first to suffer from secondary or pressure atrophy such as occurs in choked disc and in glaucoma. It is probable, therefore, that the so-called nasal hemianopsia which has been observed in brain tumor can be explained in this manner. Furthermore, the pathological findings at our command tend to show that pressure from a distended third ventricle produces bitemporal hemianopsia rather than binasal. Siemerling[1] calls attention to a chiasm almost divided by a greatly distended third ventricle, thereby giving rise to bitemporal hemianopsia. A similar condition is observed in simple chronic glaucoma, a pathological process which primarily is practically confined to the

[1] Archiv für Psychiatrie und Nervenkrankheiten, Band 20, Heft 1.

optic nerve. It is reasonable, therefore, in the regressive stage of choked disc of brain tumor origin, in which the pathological process as an end-result is similar to that of glaucoma, *i. e.*, a secondary atrophy, to account for the early shrinkage of the nasal field in the same manner as in glaucoma, rather than by the pressure of the carotid arteries upon the chiasm. The remarkable distortion and alteration of the visual tracts which are observed in disease in and about the chiasmal region of the brain, without any marked field defects, are facts worthy of note and will illustrate the amount of pressure and damage which the chiasm may undergo without marked perimetric evidence of disease.

Ophthalmoscopically and perimetrically these two conditions are separate and distinct entities although in most instances part of the same general process, in which papilledema may first appear, followed by a papillitis and a subsequent neuro-retinitis.

Three clinical possibilities may arise: (1) The papilledema may be so rapid and severe in its onset that it is promptly followed by atrophy without marked evidence of an intervening inflammatory stage which usually accompanies papillitis and neuro-retinitis. In this instance the blind spot will be enlarged for form and colors, extending to and involving the point of fixation, and peripheral fields will contract rapidly as the atrophy advances. Blindness usually follows.

2. If the proper remedial measures are applied, there may be a rapid recession of the swelling, without any inflammmatory symptoms, and with a moderate degree of atrophy. In this group of cases, there will be a primary enlargment of the blind spot with little other immediate perimetric change. The degree of atrophy, which usually is slight, will depend upon the extent and the duration of the papilledema. Peripheral contraction will be in direct proportion to the atrophy and will be a remote manifestation.

3. The third clinical type, perhaps the most fre-

quently encountered, is characterized in successive stages by papilledema, papillitis, neuro-retinitis and atrophy. Perimetrically, there is first an enlarged blind spot of Mariotte, followed by lowered central vision, a cæco-central scotoma and an immediate peripheral loss, concentric or sector-like in character. Remotely, central and peripheral vision may be lost entirely, or if a decompression relieves the condition, central vision may improve some, the cæco-central scotoma may become less marked, while peripheral contraction of fields may be less marked than during the active inflammatory stage. Almost any type of choked disc, if relieved by decompression before blindness supervenes, will show a rapid improvement in central and peripheral vision only to be followed shortly by a second reduction in central vision and a contraction of peripheral fields because of the residual atrophy.

Papillitis as a rule appears alone or associated with neuro-retinitis. As in papilledema, there is an enlarged blind spot, but associated with this symptom, even in the early stage of the condition, there also is peripheral field disturbance, in direct proportion to the degree or severity of the inflammation. The enlarged spot does not appear as an isolated sign of field change.

Pseudo-Optic Neuritis.—It is difficult at times to differentiate between a true papillitis and a pseudo-papillitis which is sometimes observed with high degrees of hypermetropia. In the few cases of pseudo-neuritis observed by the author, in which field studies were made, there was no appreciable increase in the size of the blind spot. This may serve as a means of differentiation between a true optic neuritis largely confined to the nerve head and the spurious forms referred to.

Visual Fields in Glaucoma.—From a perimetric standpoint a division of glaucoma into an acute and chronic stage is most satisfactory. The latter group may be further subdivided into simple non-inflamma-

tory, or glaucoma simplex, and chronic inflammatory. In the latter form, the acute fulminating attacks are but incidents or a succession of incidents which follow the case throughout its course. For purposes of simplicity a division into acute and chronic forms will suffice.

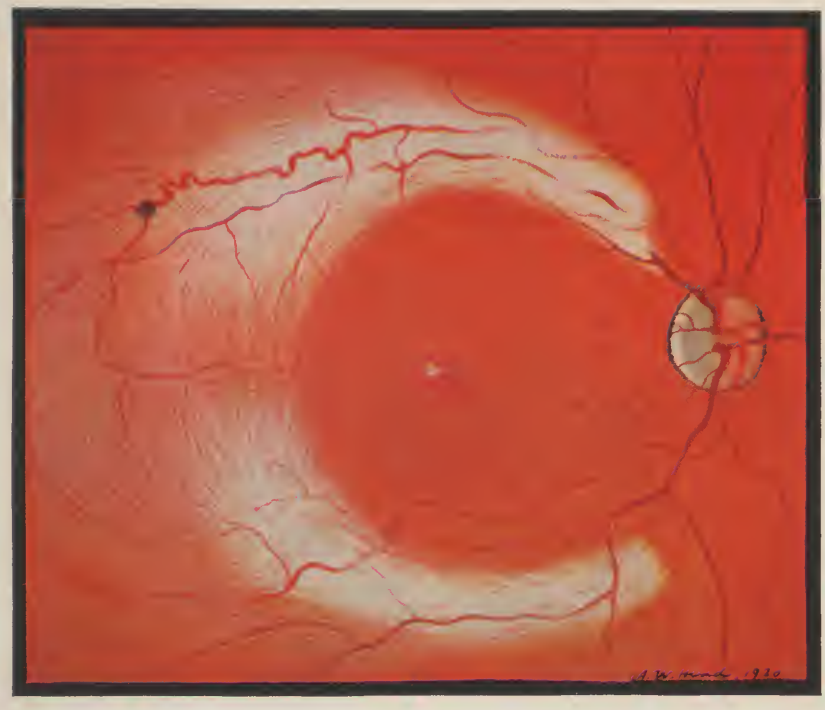
In the congestive varieties visual disturbances, both central and peripheral, are due largely to clouding of the media and to disturbance of the retinal circulation. As the intraocular tension rises and equals or surpasses that of the venous or capillary pressure, venous stasis and obstruction to the outflow of blood is a natural consequence. Such attacks may be so severe as to cause blindness in a very short time. Under proper treatment central and peripheral vision may be partly preserved, although some permanent damage is sustained in each acute attack. As in the more slowly developing non-congestive types, one of the earliest changes in the visual field is a nasal contraction. This is due to a tendency to constriction of the circulation of the temporal retina. The blood supply through the central retinal artery, is carried by a longer and more circuitous route to the temporal than to the nasal retina. It is natural, therefore, that the peripheral temporal vessels will suffer earlier than the direct nasal branches. When it is possible to take fields in these acute attacks, a contraction of the nasal field will be found to be greater than that of the temporal. This is exactly what is found as a rule in glaucoma simplex, but the reason for the cutting is totally different. In the acute variety it is largely due to vascular obstruction; in non-inflammatory glaucoma it is due to nerve fiber block or degeneration. The first is apt to be temporary if prompt treatment is instituted; the latter as a rule is permanent or nearly so even though suitable treatment is applied. The circulatory balance may be restored in the former; nerve fiber degeneration may be arrested in the latter but regeneration of atrophic nerve fibers does not take place.

Aside from the rapid loss of the entire visual field, which is most marked nasally, and its rapid recovery coincident with the relief of the intraocular pressure, interest in perimetric symptoms centers in the chronic forms of glaucoma or more correctly speaking, in the late stage of glaucoma whether congestive or non-congestive. It should be noted in passing, however, that acute attacks which so often appear when the disease has advanced well into the chronic stage, are particularly apt to result in permanent blindness, if not promptly relieved and always leave the visual field as well as central vision worse with each recurrence.

In chronic glaucoma, recognized departures from the normal field manifest themselves: (1) In early loss of the nasal field; (2) in sector-like defects of the superior or inferior nasal quadrants; (3) in enlargement of the normal blind spot of Mariotte–Bjerrum's sign or scotoma; (4) in concentric contraction of form and colors; (5) in preservation of central vision for form and colors even though peripheral fields are cut to a small central area; and (6) in almost complete loss of peripheral field with (*a*) preservation of a small temporal area and a small central island or (*b*) total loss of central vision. While the clinical experiences of various men may vary much, in general the order in which these symptoms have been noted is the order of frequency, as well as approximately the order in point of time, when the phenomena appear in the life history of average cases.

Early nasal loss is due to the anatomical arrangement of the nerve fibers. If the reader will refer to Fig. 1, in which is diagrammatically and graphically presented the distribution of the optic nerve fibers, it will be noted that the temporal fibers have a decidedly arched direction. That this distribution is correct is easily demonstrated in the Bjerrum sign which will be discussed later, and in Roenne's step. In addition, Plate V, which is a reproduction of a most remarkable distribution of persistent medullary nerve fibers, re-

PLATE V



An Unusual Case of Medullated Nerve Fibers, which also Illustrates the Normal Distribution of the Retinal Nerve Fibers. (Courtesy of Mr. B. T. Lang.)

ported by B. T. Lang,[1] graphically illustrates the course of the fibers. It requires no stretch of the imagination, therefore, to visualize the long arched direction which the temporal fibers take to reach the periphery as contrasted with the short and more direct radiation of the nasal fibers. In the stretching process the long fibers to the temporal periphery naturally are affected first. Another factor equally important plays a prominent role. As the excavating process advances, the undermining as a rule is more marked on the temporal, the upper and lower edges of the disc than on the nasal side. Vessels and nerve fibers are crowded to the nasal side normally and in the formation of the glaucomatic cup. The fibers in contact with the exposed sharp scleral edge must yield early in the stretching process, as will be observed in the development of the Bjerrum scotoma. This particular phase of the process is responsible for the second or *sector-like defect* which is observed in the fields of glaucoma patients. The nasal sectors are the first to show contraction, developing into complete nasal loss as both upper and lower quadrants become involved. In point of time, it is probable that these nasal sector defects precede the complete loss of nasal fields. As they are early signs, they are often overlooked unless careful studies are made of peripheral and central fields. When well developed these sectors form Roenne's steps (Fig. 85). This peripheral step-like formation may occur with or without the Bjerrum sign. In development they are like the Bjerrum sign and in most instances a part of this sign. When the Bjerrum sign is absent, the short fibers have as yet escaped damage, whereas the long peripheral segments have undergone physiological and pathological block, which results in atrophy.

Bjerrum's Sign.—While the last-named defect has been called after Roenne, it is in point of fact a part

[1] Tr. Ophth. Soc. of the United Kingdom, 1920, 40, 178.

of the sign to which Bjerrum's name has been attached. The fact that it may exist alone makes it of sufficient importance to specially designate it as Roenne's step. The group of changes which may be included under "Bjerrum's sign" are perhaps of greatest importance because they occur for the most part in a section of the field which is vital, and because when present, neither patient nor surgeon can sidestep the responsibility of prompt action if the process is to be brought to a standstill. It is difficult to discuss this symptom without mentioning Seidel's sign. This, however, will be taken up later.

The reader's attention has been called to the fact that the glaucomatic excavation advances on the temporal side, above and below more than on the nasal edge of the disc. The overhanging vessels are first lost in these positions. In fact it is especially in the upper and lower temporal quadrants of the disc that the undermining is greatest. This is important because the scotoma when present is always toward the nasal side of the field. Temporal fibers are involved very late and the temporal field is the last to go. Referring again to Plate V, the direction of the medullated nerve fibers gives one a good idea of the direction which the scotoma is apt to take. When complete the scotoma is comet in shape or sickle-like. It extends from the upper or lower edge of the blind spot above the point of fixation to the raphé in the center along the horizontal meridian. If the process is complete above and below, an annular scotoma will be present in which the blind spot of Mariotte is included.

The development of Bjerrum's sign is interesting. In Figs. 78 to 81 are shown the evolution of such a scotoma which developed in a patient under the author's care. Although the blind spot was included, the scotoma originally developed above the fixation point as a detached area, and after a time the blind spot and scotoma merged into one. A similar Bjerrum sign was begun below the fixation point. This was arrested

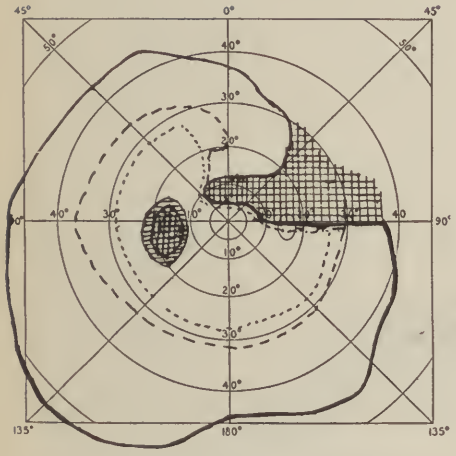


FIG. 78

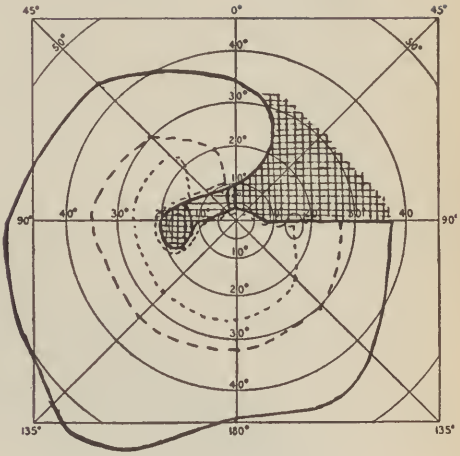


FIG. 79

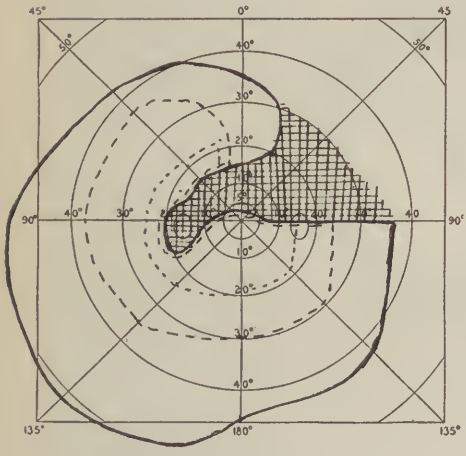


FIG. 80

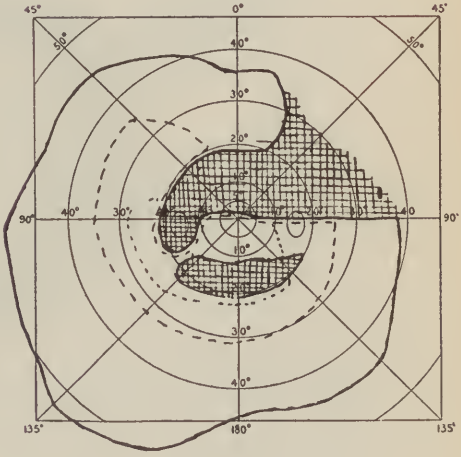


FIG. 81

FIGS. 78 to 81.—Illustrate the evolution of a Bjerrum scotoma. In Fig. 81, a beginning Bjerrum scotoma is shown in the lower part of the field. This was relieved by a sclero-corneal trephining after the usual broad iridectomy failed to arrest the process. The patient was twenty-eight years of age.

by a trephining after the usual broad iridectomy failed to produce the desired result.

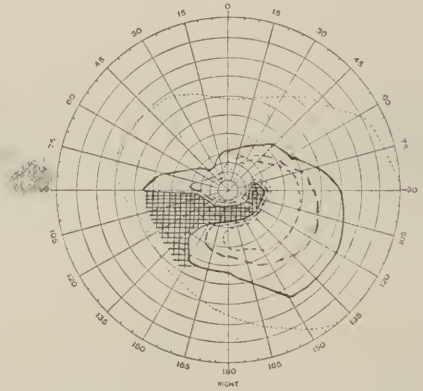


FIG. 82.—Bjerrum scotoma in a case of glaucoma simplex. O. D. V. = 6/7.5.

Instead of developing as a detached blind area above or below the fixation point, this sign may begin as an enlargement of Mariotte's blind spot which may grad-

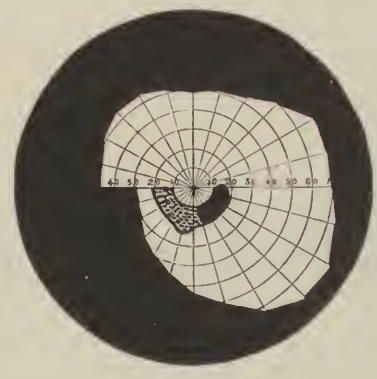


FIG. 83.—Bjerrum's sign and Roenne's step. The lesion to the bundles of optic nerve fibers is at the upper temporal edge of the disc as shown in Fig. 84. (Courtesy of Col. R. H. Elliot and Publishers.)

ually extend to the raphé or even to the periphery. In the author's experience, however, most Bjerrum signs begin as detached areas above or below the fixation center between the tenth and twenty-fifth degrees.

The scotoma at first is indistinct for green, then relative in which green is lost first, and finally it becomes absolute.

In order to detect the first sign of its presence, a small green stimulus is the best to employ. In the test the patient as a rule hesitates and when closely questioned will volunteer the information that the

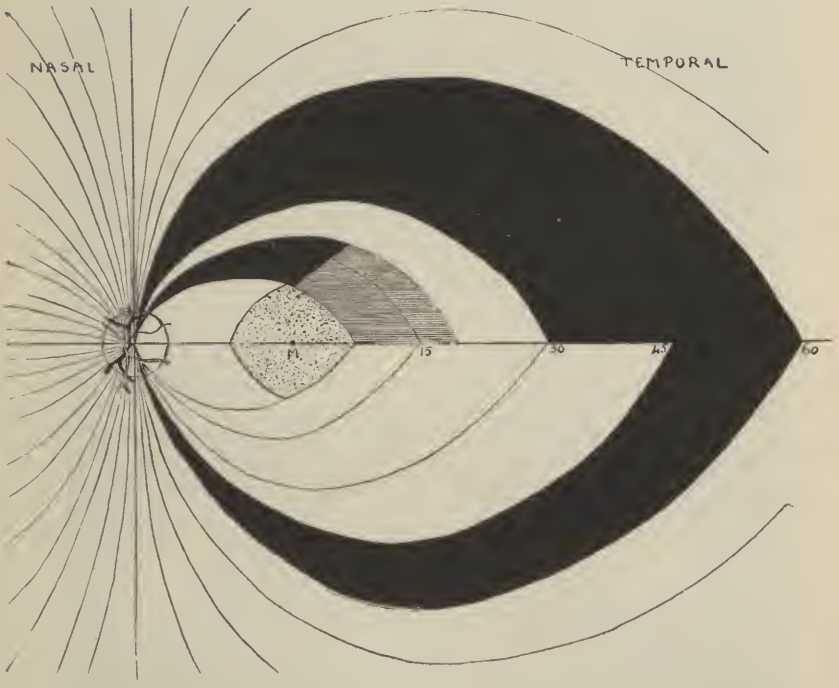


FIG. 84.—The diagram shows roughly and diagrammatically the damage to the nerve bundles of the retina, which would correspond with the visual defects in Fig. 83. (Courtesy of Col. R. H. Elliot and Publishers.)

green looks pale or white. This indistinct scotoma for green the author has been able to elicit when the minutest test object for white failed to disclose any loss of sensitivity.

The importance of this sign cannot be overestimated. Its early detection may hasten the operative procedure, which has been withheld, because the operator is

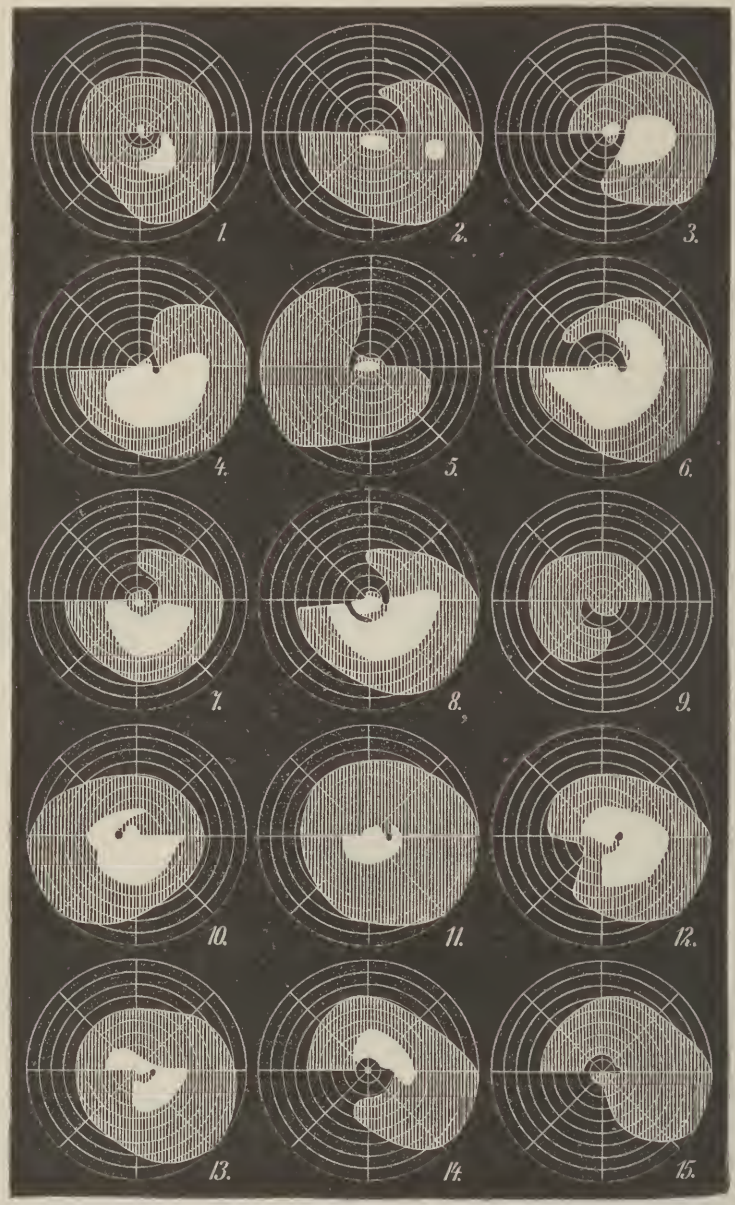


FIG. 85.—Roenne's steps. Reproduced from Col. Elliot's book on glaucoma. These charts graphically illustrate the type of step-like formations which Professor Roenne encountered in glaucoma. (Courtesy of Col. R. H. Elliot and Publishers.)

sustained by a false assurance that "all is well" because central vision has not suffered and peripheral fields show but moderate contraction. Failure to relieve the intraocular tension when this sign is present hastens the remarkable reduction of the field to a small island around the point of fixation, as is observed not infrequently in advanced cases. Peripheral loss when combined with a ring scotoma formed by a double Bjerrum sign rapidly develops into the sixth type of change to be discussed.

Seidel's Sign.—Seidel's sign is a phase of the comet-shaped defect just discussed. If carefully studied, the blind spot of Mariotte will show a spur above or below when the Bjerrum sign begins at the blind spot. Seidel found a crescent-shaped defect arching toward the nasal periphery. Although Seidel[1] deserves much credit for the exhaustive studies which he made, it is evident that his sign is but a part of the Bjerrum sign, and it will be less confusing to regard Seidel's work as a contribution to the development of the Bjerrum symptom.

Elliot's Sign.—Similar in character to the sign of Seidel is that of Elliot. The latter author conceived the idea that instead of a single point to the crescent there should be several of these points. Working with the Elliot scotometer, which is described on page (85), he was able to demonstrate to his own satisfaction the correctness of his early belief.[2] Others who have used this scotometer have developed the same irregularities of the enlarged blind spot in glaucoma. While there can be no doubt that there are irregularities in the crescentic enlargement of the blind spot, it is possible that the mechanical groove in which this instrument works has a tendency to a greater accentuation of this irregularity than actually exists. It is the author's belief that the flexibility of the hand-manipulated stimulus on the ordinary Bjerrum screen

[1] von Graefe's Archiv. f. Oph., 1914, **88**, 102.

[2] Elliot: A Treatise on Glaucoma, p. 270.

might have a tendency to smooth out at least some of these sharp angles. This, however, is not vital. Both Elliot and Seidel have given much study to blind spot enlargement, and their contributions have been timely in awakening the profession to a more careful routine study of the blind spot in every suspected case of glaucoma.

Before leaving Bjerrum's sign, of which Roenne's step, Seidel's and Elliot's signs form a part, attention should be drawn to the fact that, when well developed, this sign frequently leads to altitudinal types of visual loss, and this without the patient's knowledge that his field of vision has become unduly restricted.

Concentric Contraction for Form and Colors.—The symptoms thus far discussed are the earliest field changes observed. Cases, however, are found in which there is only a contraction for form and colors, the contraction being more or less concentric. When this contraction has progressed to the ten or fifteen degree circle, it is clearly evident that it has passed through the evolution of peripheral loss and possibly a double Bjerrum sign, and is far advanced. When the concentric contraction is only moderate in degree, careful analysis will often reveal an irregularity which ordinary routine methods do not disclose. Few cases will undergo even moderate regular contraction without paracentral defects. In this it differs from ordinary types of descending atrophy. The atrophy is essentially due to pressure and the stretching process, in which nerve bundles or even nerve fibers suffer in the destructive process.

Preservation of Central Vision.—One of the most characteristic features of chronic non-inflammatory glaucoma is the remarkable preservation of central vision, even though peripheral fields may be cut to a very small central area. It is unfortunate in that many patients, because of good central vision, fail to consult an oculist until the disease is well advanced. Since the nerve fibers between the tenth and twenty-

fifth degrees are so frequently involved, the question naturally arises, why do the macular fibers escape? The answer, in all probability, is found in the great number of nerve fibers which supply the macular area. The papillo-macular fibers in the head of the optic nerve comprise about one-fifth of the entire nerve. They are distributed to a very small area. It is likely, therefore, that although many of the macular fibers suffer during the development of a Bjerrum sign, a sufficient number remain intact to preserve useful central vision until the last. In this central island of good central vision colors are also preserved although green becomes difficult to recognize. (See Fig. 83.)

A Small Island Preserved in the Temporal Field, With or Without Central Vision.—As a terminal stage of the process, one may find a small island in the temporal field in which form at least is recognized. The nasal field is first to go, then the more peripheral temporal field with midtemporal and central areas intact or at least functionating. In glaucoma simplex, central vision may be preserved until the last. If the disease is of the chronic inflammatory type, central vision becomes involved fairly early and an island in the midtemporal region, in the upper or more frequently in the lower nasal quadrant, will be all that remains of functionating retina. (See Fig. 87.)

It is evident to the reader that the fields in glaucoma are varied but never bizarre. They follow a natural order of development, different it is true in different patients, but in all cases easily understood. The anatomical distribution of the nerve fibers and the point on the scleral ring, where intraocular pressure may cause most damage, furnish logical reasons for each and every case. That nerve bundles are picked out is shown for example in Bjerrum's sign and in Roenne's step. Along the borders of the scotoma, form and color limits are the same as in the paracentral region. This is due to the fact that contiguous nerve fibers are intact. If quantitative methods of study

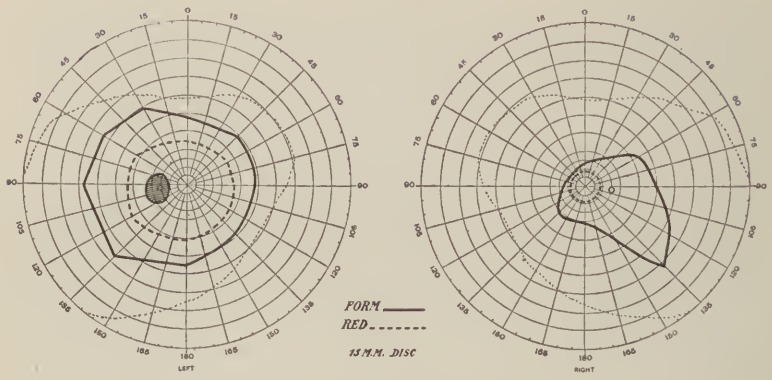


FIG. 86.—Chronic glaucoma.

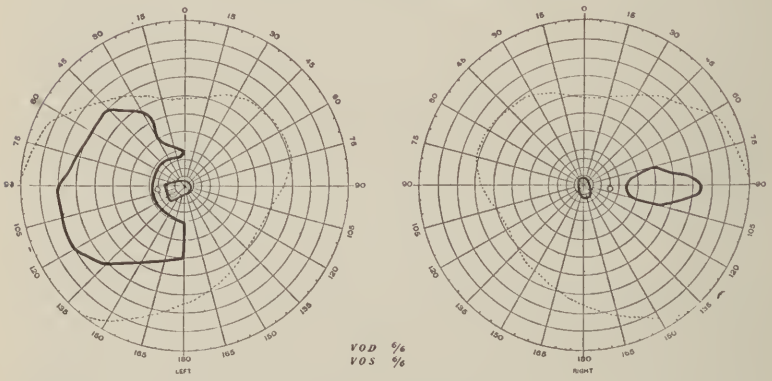


FIG. 87.—A typical field of advanced chronic glaucoma taken with a 1° test object. Central vision 6/6 in each eye. Both eyes blind to color. (Reber.)

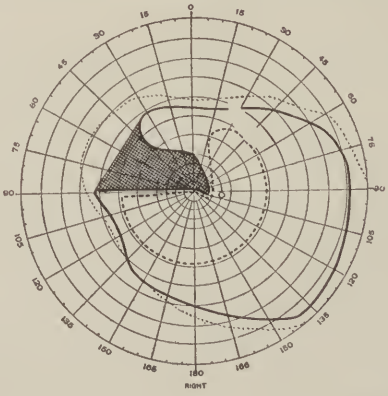


FIG. 88.—Bjerrum's form of scotoma in glaucoma.

are employed, there will be no variation to the dividing line, providing, of course, the limits of the scotoma do not reach too far into the periphery. In the periphery, form and colors will follow the natural laws of peripheral retinal sensitivity.

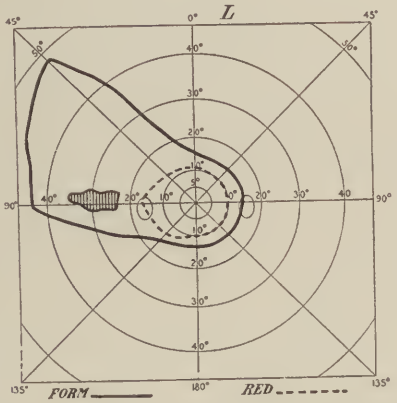


FIG. 89.—Indistinct scotoma in a case of chronic glaucoma. Marked cutting of nasal field.

DISEASES OF THE OPTIC NERVE PROPER.

Diseases of the optic nerve proper from the eyeball to the intracranial portion of the nerve, just before it enters the chiasm, form a clinical group which may be advantageously discussed collectively. It is impossible, for example, to draw a sharp dividing line between choked disc and optic neuritis of the retrobulbar portion, as choked disc is naturally accompanied by an ascending optic neuritis, or may be associated with a descending neuritis. It is also true that an optic neuritis and an optic atrophy may have their origin in the chiasm or posterior to it; but the symptom-complex which characterizes a neuritis or atrophy in the chiasm or posterior to it differs materially from the group of symptoms which accompany an orbital retrobulbar neuritis or atrophy. Furthermore, the anatomical environment of this portion of the optic nerve predisposes it to injuries and disease not met with in the

calvarium. The frequent infection of the orbit from the nose and the accessory sinuses, the exposure of the eye and orbit to external injury, the passage of the nerve through the small optic foramen, and the continuation of the subarachnoid and subdural spaces into the sheath of the optic nerve are further factors which make the orbital part of the nerve particularly vulnerable. Anatomical relations of the chiasm and optic tracts to other parts of the brain, on the other hand, render this part of the visual pathway susceptible to disturbed function, characterized by special symptom groups.

Optic Neuritis.—The retrobulbar portion of the optic nerve is subject to two types of disease—inflammation and atrophy. Three forms of neuritis are recognized: (1) Diffuse interstitial neuritis; (2) neuritis of the papillo-macular bundle or axial neuritis; and (3) perineuritis. The first and third forms are closely related, differing only in origin and perhaps in degree. A perineuritis, although a distinct entity at first, eventually develops into a diffuse neuritis if it is at all severe. The second form, or axial neuritis, in which the papillo-macular bundle is primarily involved, is a definite type of inflammation in which a central scotoma is a constant feature.

The diffuse interstitial variety of retrobulbar neuritis may or may not be associated with a manifest papillitis. Some cases are accompanied by a moderate amount of swelling of the nerve head, but a true papilledema, as a rule, is not observed. Changes in the field usually take the form of bizarre peripheral contractions for form and colors, with a tendency to sector-like defects. This irregular contraction is apt to occur when the neuritis is due to phlegmon of the orbit, sinus disease or to any local form of contact infection. Under these circumstances, neuritis may develop first by extension of the inflammation and a local spot of inflammation of the optic nerve will mark the beginning of a diffuse neuritis which is sure to follow. In this particular

type, a papillitis is apt to be associated with an enlargement of the blind spot of Mariotte. Sector-like defects are apt to develop in the peripheral fields.

In other instances the toxic process may be carried by the blood stream and a more evenly diffused inflammation is the result as evidenced by greater regularity of the peripheral contraction. Central vision is lowered in either type of diffuse inflammation, and in addition to the enlarged blind spot of Mariotte, when a papillitis is present, there may be an indistinct, relative or absolute central scotoma. In fact, scotomata may occur in any part of the field.

The ophthalmoscopic picture will vary with the stage and extent of the disease. In the early stages, a characteristic feature of retrobulbar inflammation is the absence of visible fundus changes. In fact the diagnosis in the dark room is made by exclusion in the absence of fundus changes. In the more severe forms and in advanced cases as the disease progresses the usual type of changes is observed.

It is rather difficult to differentiate many of the types of retrobulbar disease, true toxic amblyopia excepted, from diffuse neuritis of central origin, if one does not bear in mind the fact that neuritis of orbital origin is apt to be unilateral in character rather than bilateral as observed in neuritis of central origin. Field changes in the latter types are about the same as those which are observed in the former unilateral variety excepting in rapidity of development. The retrobulbar form is more acute and perhaps more severe if not promptly relieved. At the same time both optic nerves may share alike as in Fig. 90.

1. *Acute Retrobulbar Neuritis.*—There is a form of acute inflammation, bilateral as a rule, and fulminating, which is the result of an intense toxemia. This special form of toxemia may be caused by any poison from within or without, infections or otherwise. Although Leber's disease is of a distinctive familial type it is a good example of this acute toxic form of inflam-

mation. The loss of the central field of vision from involvement of the papillo-macular bundle is not so much in evidence, or at least occurs only as a part of a rapid and diffuse inflammation of the optic nerve. During the course of twenty-four to forty-eight hours central vision may be reduced to the counting of fingers at a foot, and peripheral vision will be reduced proportionately. The perimetric symptoms will depend upon the degree of the inflammation and the extent of the subsequent atrophy. Central scotoma, however, is not so frequently in evidence as in the chronic variety.

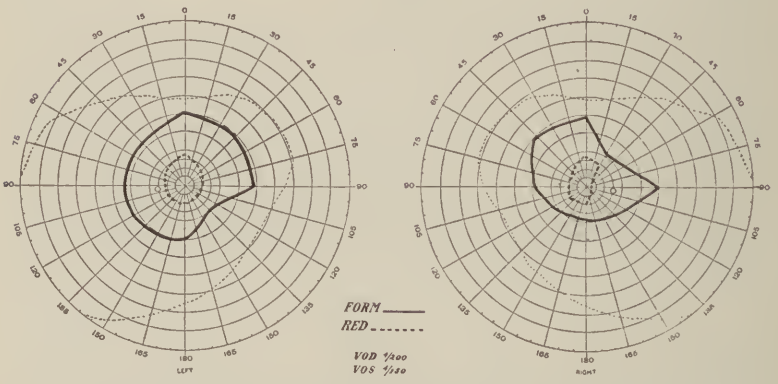


FIG. 90.—Acute retrobulbar neuritis, four days after onset.

In Fig. 90 are recorded the fields of a boy of seventeen years who suffered from a most violent retrobulbar optic neuritis, tuberculous in origin, four days before the above fields were taken. Green was entirely lost, and red and form fields were reduced considerably. Recovery in this case was rapid but not complete. Central vision became 20/70 in each eye. Form fields enlarged to fairly normal limits, but red remained contracted, and green became visible in the central field.

2. *Toxic Amblyopia.*—Toxic amblyopia, or the chronic variety of true retrobulbar neuritis, perimetrically is as distinctive and characteristic as the clinical phenomenon which characterizes it. It begins in the

ganglionic retinal cells, and secondarily spreads to the nerve fibers of the papillo-macular bundle. Ordinarily, however, it is classified as a type of retrobulbar neuritis. Bilateral pericentral scotomata is the rather uniform perimetric finding in this condition. Lohmann calls attention to Edinger's dictum "that a high degree of functional activity involves an increased morbidity," as especially applicable to the papillo-macular bundle of the optic nerve. The process usually seems to be limited to this part of the optic nerve, although the peripheral field has been found to be involved in some instances. Subjectively, the patient complains of a

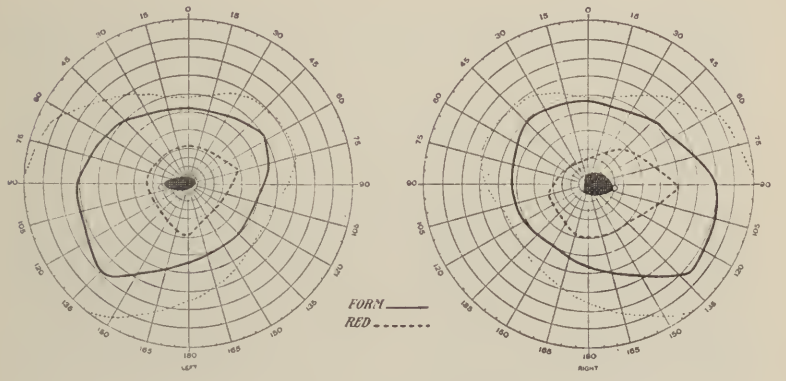


FIG. 91.—Toxic amblyopia.

haziness in central vision, indirect vision remaining normal. This blind area is bilateral and is negative in character; that is, although the patient may be conscious of a haze, the disturbed area can only be mapped out by perimetry.

The blind area forms a horizontal oval area which includes the macula, and may include the blind spot of Mariotte. It may be indistinct, relative or absolute. The stage and severity of the neuritis will determine this. A characteristic of this form of central scotoma is the presence of an absolute scotoma in a large relative area. The scotoma for white and blue will be smaller than that for red and green, the absolute

blind spot being situated centrally or eccentrically in the relative area. Bär[1] believes that two absolute scotomata may be found present—one at the point of

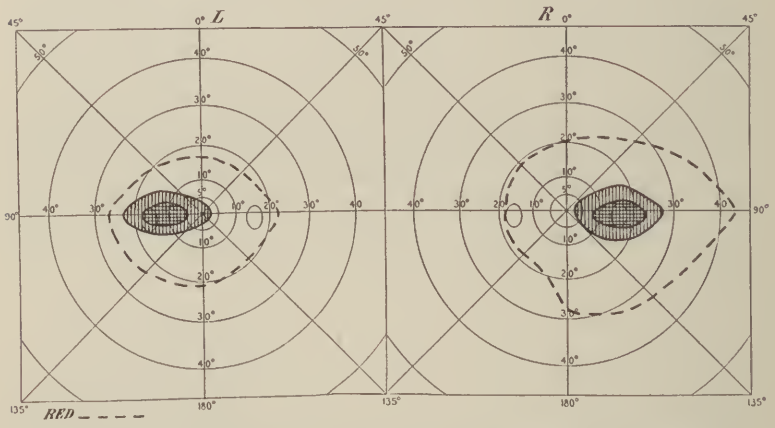


FIG. 92.—Toxic amblyopia. Typical absolute scotoma in a relative area. Form fields normal. (Reber.)

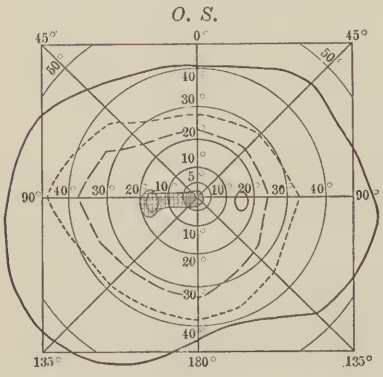


FIG. 93

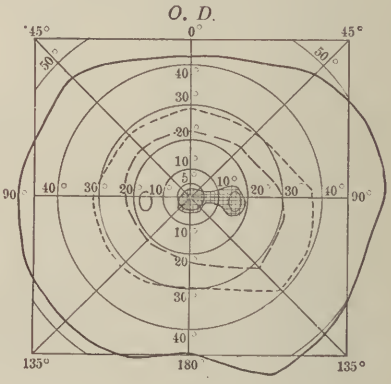


FIG. 94

FIGS. 93 and 94.—Toxic amblyopia (wood alcohol). Ten months' duration. *O. D. V.* 3/150. *O. S. V.* 3/150. Bilateral, central scotoma, including the blind spot of Mariotte. Moderate contraction of form and color fields. Note unusual contraction of the blue field. Test object 2°;———— Form; — — —Blue; — — — Red.

fixation and one in the normal blind spot, being connected by a band of relative scotoma. The oval area

[1] Archiv f. Augenh., vol. **54**, 291.

extends from the fixation point toward the blind spot. The scotoma is therefore usually pericentral rather than central. If the peripheral field is involved, Bär believes it is an indication of the involvement of the central nervous system. (See Figs. 93, 94, 95.)

In Fig. 96 are recorded the fields of retrobulbar neuritis of obscure origin. The central blindness followed the removal of a foreign body from the cornea. Although central vision is now reduced to 20/40, the scotoma is just beneath the point of fixation and is connected with the enlarged blind spot by an area blind to colors but not to form.

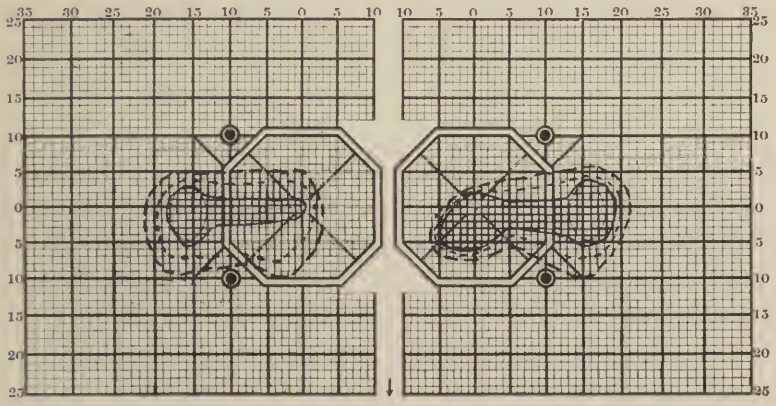


FIG. 95.—Same fields as in Figs. 93 and 94. Central scotoma taken on the Lloyd stereo-campimetric slate. Central scotoma largest for blue in both eyes. Test object $\frac{1}{2}°$.

Perimetry is of value in making a prognosis in this form of optic-nerve disease. As green is the first color to disappear, it is also the last to be recovered, if recovery is complete. If recovery takes place, the absolute scotoma may become smaller, and blue may be restored, followed in order by red and green. In severe cases, recovery is rarely complete. A relative, and sometimes an absolute, scotoma will remain.

It is interesting to recall the article of Fergus which appeared in the *British Medical Journal*, Decem-

ber 29, 1906, on "Sympathetic Amblyopia." Fergus found a condition in sympathetic ophthalmia which he called sympathetic amblyopia. In the cases referred

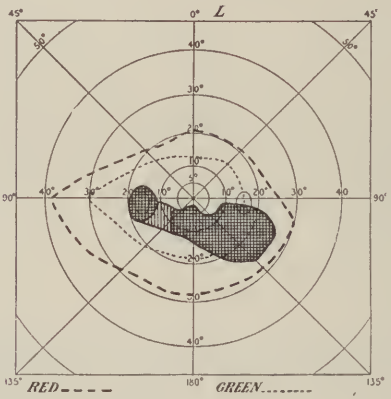


FIG. 96.—Retrobulbar neuritis of obscure origin. Enlarged blind spot of Mariotte. Relative and absolute scotomata.

to, inflammatory symptoms were absent, and perimetrically, Fergus found a concentric contraction with some, but not complete, amblyopia. These obser-

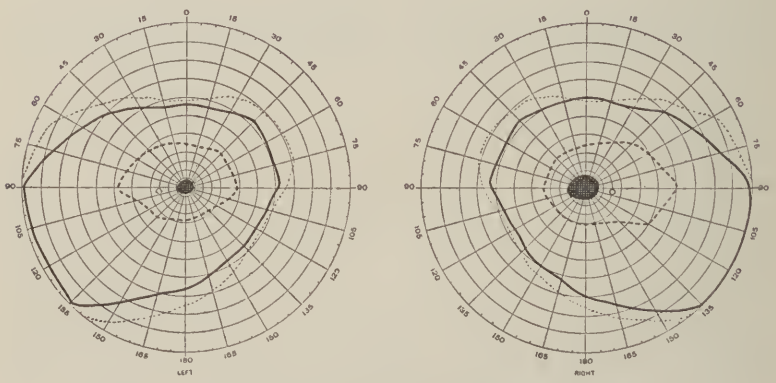


FIG. 97.—Toxic amblyopia of diabetic origin. (Reber.)

vations have been confirmed by other investigators, and in some instances an oval central scotoma, characteristic of toxic amblyopia, was found.

Field Changes in Accessory Sinus Disease.—This phase of perimetry, in recent years, has received unusual but justifiable attention. It has opened up a field for study which is only second in importance and clinical value to that of glaucoma, and lesions of the brain. It will not be possible to mention each contribution which has been made to this phase of the subject in the last ten years. For a more careful study of each paper which has contributed to the summary of our knowledge the reader is referred to the bibliography which the author hopes includes all contributions of value. It would be remiss, however,

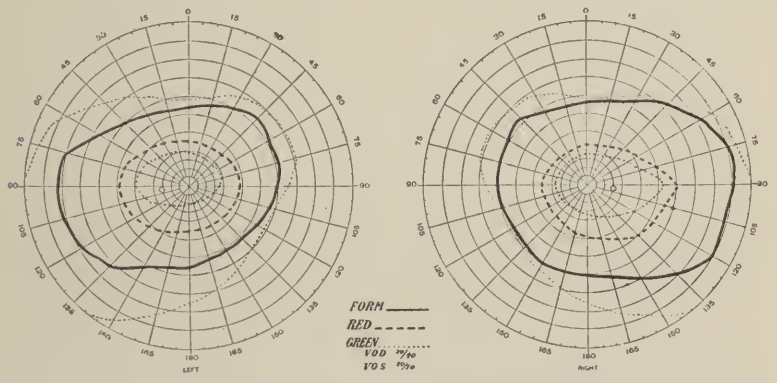


Fig. 98.—Retrobulbar neuritis, postinflammatory stage.

if we failed to call attention to the work of Van der Hoeve, who perhaps more than any other single individual, pointed the way to the recognition of the relation between accessory sinus disease and disturbance of the function of the visual pathway.

In order to thoroughly understand the changes which are observed, a brief review of anatomical relations is necessary. The optic foramen and the regional anatomy about it furnish the key to the situation. The optic foramen is in close proximity to the sphenoidal sinus, separated from it by a thin parchment-like membrane. In abnormal development the sphenoidal sinus may extend outward and underneath the foramen.

The posterior ethmoidal cells may also be in close contact. Inflammation, therefore, of these cells may have an immediate and direct effect upon the optic nerve and its coverings. Schaeffer has shown abnormal development of the frontals to extend back to the apex of the orbit—a condition which easily explains optic nerve involvement in frontal sinusitis. The dural sheath of the brain and of the optic nerve is continuous with the periosteum which lines the optic foramen making it possible for toxic materials to pass from a sinus directly into the subdural spaces.

The posterior vein of Vossius enters the optic nerve in the optic foramen, occupying in it a central position, and passes back toward the chiasm. Into this vein pour the tributaries from the nose and posterior parts of the orbit. This vascular system, therefore, furnishes another direct route from infected areas directly into the optic nerve substance and into the papillomacular bundle. These are the more important anatomical relations which will help to explain the complications of the visual pathway in nasal accessory sinus disease. The extension of bone necrosis in advanced cases and the larger vascular channels draining nose and orbit which empty into the cavernous sinus will explain some of the more destructive processes.

Perimetric Symptoms.—Most important, because of its early appearance, is enlargement of the blind spot of Mariotte. Fuchs was the first to call attention to the fact that the peripheral fibers of the optic nerve supply the retinal areas immediately surrounding the disc. It is probable too that the peripheral position of these fibers is maintained back through the nerve, as other fibers of the nerve are found to remain in their same relative position throughout. For example, temporal fibers are found on the temporal side of the chiasm. Enlargement of the blind spot, therefore, to which Van der Hoeve first directed our attention, admits of easy explanation. The peripheral fibers

of the nerve suffer first with a consequent enlargement of the blind spot. This enlargement may be indistinct, relative or absolute. It is a question of degree and of the severity of the process.

As to the exact means of its production, there is some difference of opinion. After all, it becomes an academic problem as to whether the inflammatory process is carried by the blood stream or is carried by extension. It is more than probable that both

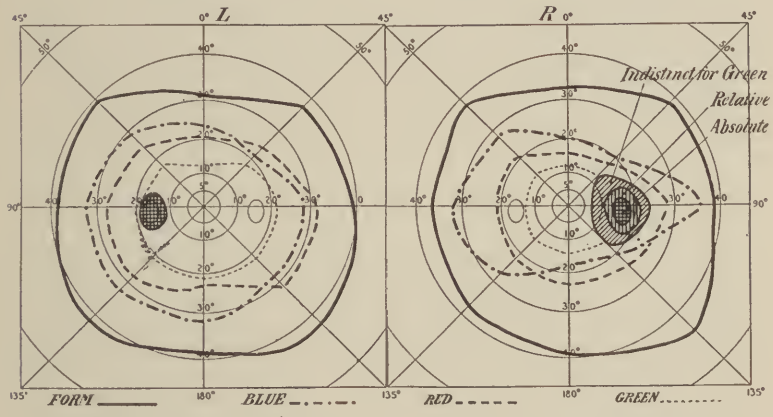


FIG. 99.—Ethmoid and antrum disease of long standing. Contraction of form and color fields. Enlargement of Mariotte's blind spot.

FIG. 100.—Ethmoid and antrum disease. Necrosis of orbital wall. Blind spot enlarged for form, surrounded by a relative enlargement for color and an indistinct scotomatous area beyond. Form and color fields contracted.

methods contribute. At all events, toxic material gains entrance to the subdural and subarachnoid lymph spaces and the peripheral fibers of the optic nerve are involved, with a consequent enlargement of the blind spot. This is an early phenomenon. In the beginning of sinus inflammation, it may be the only demonstrable sign of invasion of the visual pathway. Its presence in sphenoidal and in posterior ethmoidal inflammations, if sought for by the proper technic, will nearly always be found and can be counted upon

as a constant symptom. Perhaps a little less frequent in anterior ethmoiditis, at least in the early stages, it nevertheless appears rather constantly as the disease

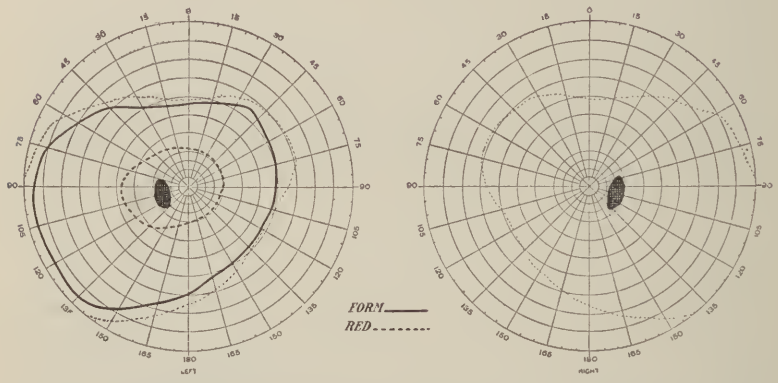


FIG. 101.—Enlargement of Mariotte's blind spot in frontal sinusitis. (Posey.)

advances because posterior ethmoiditis is but a second step to anterior involvement. In those cases, too, in which the frontal sinus shows an unusual extension

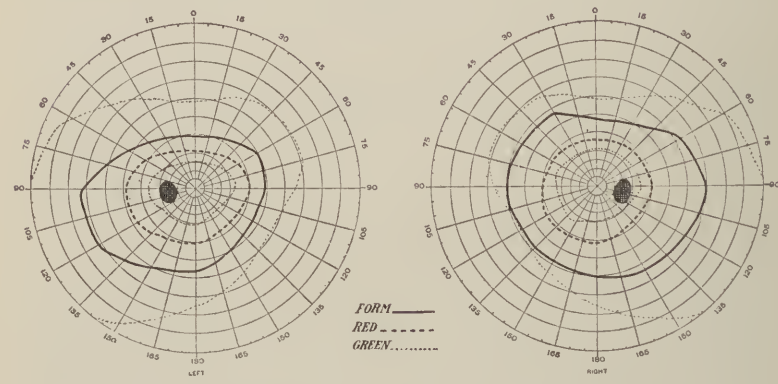


FIG. 102.—Enlarged blind spot. Chronic posterior ethmoiditis.

along the roof of the orbit it may also be a sign which is of positive value although during life such abnormal frontal may be difficult to recognize. In disease of the maxillary sinus, an enlarged blind spot, if present at all, is a late complication and is associated with

other objective and subjective evidence of grave optic nerve involvement. A toxemia carried from the sinus produces a more general effect upon the visual structures. In fact, visual disturbances associated with maxillary disease is more often the direct result of bone necrosis following a long-standing process.

Central Scotoma.—Many cases have been observed in which subjective evidence of disturbances of the visual function is early and marked. Central visual acuity is lowered and the patient becomes acutely conscious of visual loss. Field studies may show that only central vision is disturbed; the blind spot may not be unduly enlarged and peripheral retinal sensitivity may not suffer any appreciable defect. On the other hand, not only central vision but peripheral fields as well may suffer rapid loss and the blind spot of Mariotte may show the usual enlargement. The posterior vein of Vossius and its tributaries furnish a mode of attack by the toxic process which explains adequately either group of symptoms. By means of the blood channel, toxic material is carried directly to the papillo-macular bundle in the center of which the vein is situated. It is the first part of the nerve, therefore, to suffer. This is a more satisfactory explanation of the primary involvement of central vision than by direct pressure from an area of disease in contact. That the macular bundle cannot long remain the only part of the optic nerve to be affected is self-evident. It is equally evident, moreover, and demonstrated also in the operating room that prompt opening and drainage of infected sinuses may give immediate relief to this visual symptom. The complete recovery from marked amaurosis with restoration of vision and without permanent changes in the visual field, after the sinuses have been opened, strengthens our convictions that infection by this vascular route is more likely than by a direct extension of the diseased process. The latter would leave more evidence of permanent damage.

The conditions thus far discussed are the visual complications of the acute part of the process. As the sinuses become the seat of chronic inflammation, to the acute symptoms are added pressure phenomena from distended sinuses, rupture of the infected material into the orbital cavity, extension of inflammation and finally bone necrosis. In any one of the conditions enumerated an optic neuritis sometimes acute and violent, at other times slow in onset, may be the result. Papillitis and even a papilledema may follow. Some question has been raised as to the possibility of a choked disc as a complication of sinus disease. In its pure type, without a papillitis, it probably never occurs, but that it does occur associated with an inflammation of the papilla is without question. In the chronic forms of the disease, the perimetric symptoms are not especially characteristic of sinus disease, but of a local infection in which there are demonstrable visual evidences of an optic neuritis. A search, however, for the seat of infection usually discloses the presence of sinus disease.

The need for radical and energetic treatment of the nasal condition in the presence of a frank unilateral optic neuritis, should not need even passing note. And yet permanent blindness has developed in many cases which might have been prevented if prompt treatment had been instituted. In Figs. 103–106, are recorded the fields of a patient under the author's care for three years,[1] who subsequently became blind from the extension of bone necrosis. The patient gave unmistakable evidence of chronic sphenoidal and ethmoidal disease, but only after one eye became blind, could the author persuade the rhinologist to resort to a radical operation which disclosed the correctness of the diagnosis. The scotoma of the left eye invaded the field from above and on the temporal side, and slowly passed down like the eclipse of the sun until the entire field was obliterated. A similar

[1] Pennsylvania Med. Jour., 1921.

process developed from above in the right eye and at present writing, blindness is complete. In this instance the necrotic process advanced from the sphenoid to the optic foramen. The fields graphically show the

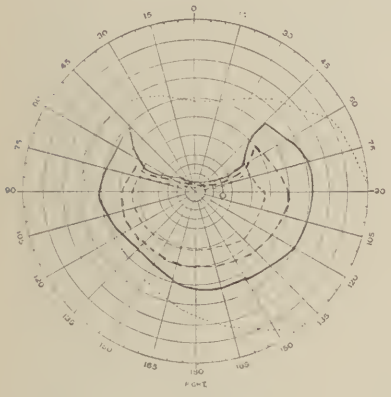


FIG 103.

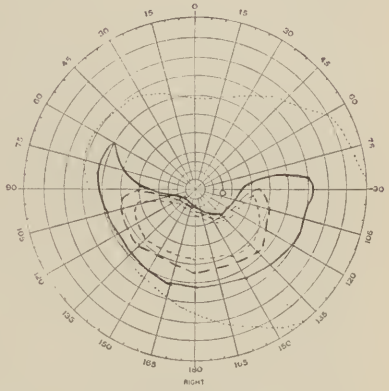


FIG. 104.

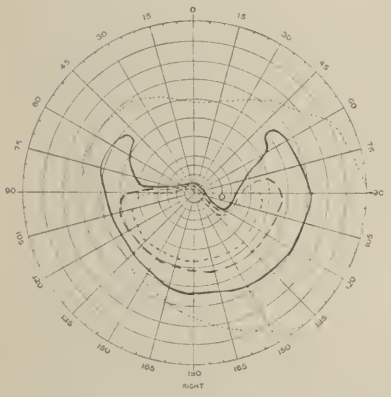


FIG. 105.

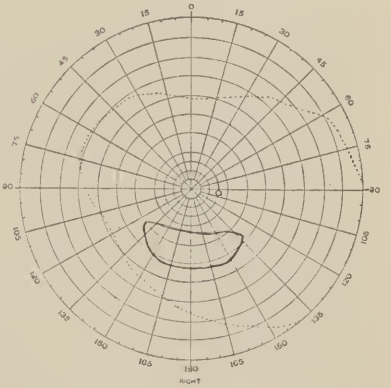


FIG. 106.

FIGS. 103 to 106.—Field studies in a case of chronic sphenoidal disease showing progressive loss of vision as the result of bone necrosis.

progress of the disease. Although the operation when performed failed to arrest the necrotic advance, it is probable that earlier interference might have saved at least part of the visual function.

In the order of frequency as causing early visual

field disturbance are disease of the sphenoid, posterior ethmoids, anterior ethmoids and frontal sinuses. In the complications arising from chronic disease, the same order obtains with the maxillary sinus added as the last.

Field Changes in Optic-nerve Atrophy.—Clinically, optic-nerve atrophy may be divided into: (1) Primary; (2) secondary atrophy; (3) consecutive or postneuritic (4) retinitic or choroiditic atrophy. Discussion of optic-nerve atrophy cannot be limited to the intraorbital portion of the visual tract, as many of the primary and consecutive atrophies do not originate within this part of the optic nerve. For convenience of discussion, however, atrophy due to disease of any part of the optic tract will be dealt with at this time. Essentially, each of these four clinical varieties has certain perimetric symptoms which are common to all. Color fields, especially the red and green, show evidence of shrinkage out of proportion to the form, yellow and blue fields. The form field suffers in any variety of atrophy, and the contraction may either be of the concentric type or may be marked by reëntering angles. Scotomata, central or peripheral, indistinct, relative or absolute, usually negative in character, also appear in all varieties. There are, however, shades of difference more or less constant which distinguish one variety from another. For example, primary or simple atrophy usually is characterized by a concentric contraction of form and color fields, whereas consecutive or postneuritic atrophy is marked by an irregular contraction with large reëntering angles. Although this is the prevailing order, exceptions are numerous. Primary atrophy due to insular sclerosis usually is the exception, and irregularities in this disease are the rule. Another example of prevailing differences is observed in retinitic and choroidal atrophy in which scotomata and other perimetric changes peculiar to the primary retinitis and choroiditis prevail in contrast to the more regular

types of primary atrophy in which scotomata are not so much in evidence.

Primary Atrophy.—This classic type is probably the most important of the subdivisions under discussion. It includes a large number due to hereditary and acquired central diseases, local pathological processes, as well as a fairly large unclassified group such as atrophy due to exposure to cold, venereal excesses, malnutrition, etc. Tabes dorsalis, or locomotor ataxia, is the classic example of this variety. An early and rapid loss of red and green fields, together with concentric contraction of form, yellow and blue fields, are the usual phenomena. The nasal field, as a rule, shows the first evidence of change. Central scotomata are not unusual. These scotomata, when present, are negative in type, and although relative at first, soon become absolute. The concentric contraction in typical cases progresses until all evidence of color has disappeared and only central fixation remains, or complete blindness supervenes. Instead of this regular and concentric contraction, irregular types are observed. The nasal field may show cutting, corresponding to the early pallor of the temporal half of the optic discs. Quadrant and reëntering angles, especially of the nasal field, early loss of fixation from a central scotoma, total loss of all light and color sense, excepting in a small area eccentric to the temporal side of the field, are occasionally observed. Price and Heed[1] report a case of binasal hemianopsia occurring in a supposed tabetic patient. Two other cases of a similar character were collected by Shoemaker[2] in 1905.

Insular Sclerosis and Paresis.—Insular sclerosis and paresis show perimetric changes of varying character. The irregularity in the findings is most characteristic, and is in harmony with the varying character of the clinical phenomena. Pallor of the temporal halves of the disc, more marked in one eye than in the other

[1] Jour. Am. Med. Assn., March 7, 1914, 62, 271.
[2] New York Med. Jour., February, 1905.

is accompanied by irregular contraction of the form fields. Central, indistinct, relative or absolute, negative scotomata are quite as constant as any of the peri-

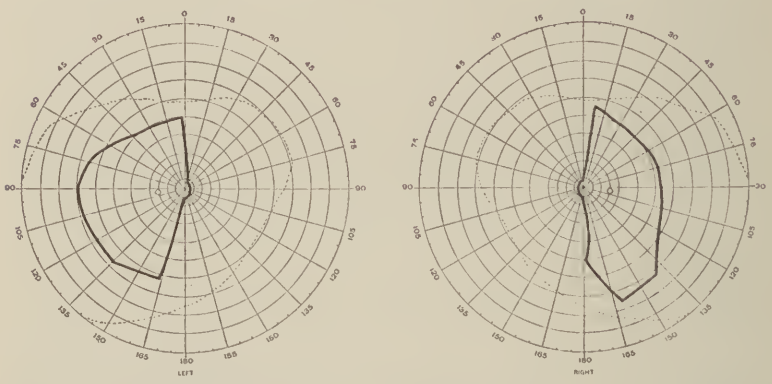


FIG. 107.—Binasal hemianopsia of tabetic origin. (Case reported by Price and Heed.)

metric changes observed. No constant perimetric changes, however, are observed, as the lesions in both of these conditions are irregularly distributed. Quad-

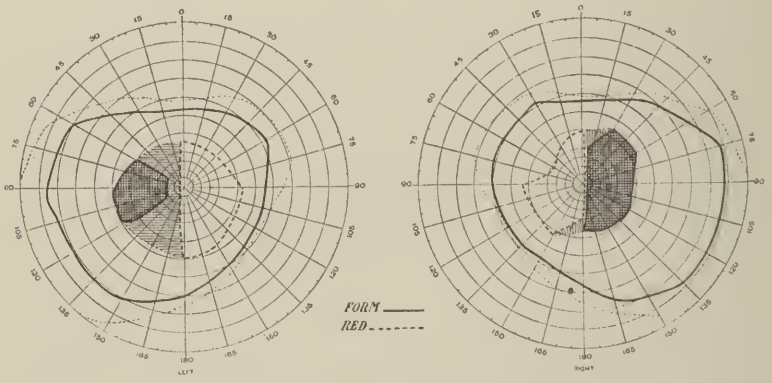


FIG. 108.—Insular sclerosis. Bitemporal hemiachromatopsia. Bitemporal absolute scotomata.

rant and hemianopic blindness, however, occur from lesions in the chiasm or in the tract posterior to it.

In Fig. 108 are recorded the fields of a classic case of

insular sclerosis with absolute bitemporal scotomata and bitemporal hemianopsia for colors. These perimetric symptoms remained constantly during the last two years of the patient's life. The form fields, however, contracted gradually. Death supervened before blindness came.

Paralysis Agitans.—Optic atrophy does not occur in uncomplicated cases of paralysis agitans. This disease, however, frequently develops in subjects suffering from a general arteriosclerosis, and perimetric changes may therefore be observed in such subjects. Atrophy is not unusual in this complication, owing to the frequent attacks of angiospasm, which may result in permanently blind areas. Irregular scotomata, quadrant and even hemianopic in type, may be elicited by perimetric study. When, therefore, perimetric changes are observed in paralysis agitans, it may be assumed that they are the result of the complications.

It is alleged that optic atrophy occasionally occurs in *chronic myelitis*, *spastic paraplegia*, *syringomyelia*, and in *bulbar paralysis*. Gowers observed optic atrophy in an uncomplicated case of chronic myelitis. It is doubtful whether similar conditions have been frequently observed in pure types of this affection of the spinal cord. If present, it strongly indicates complications.

Cases of atrophy in *Friedreich's ataxia* have also been occasionally observed. It more frequently happens in hereditary cerebellar ataxia, a symptom group which is now separated from that of Friedreich's ataxia. In either case, the presence of atrophy raises the question of a possibly luetic condition, although a few undoubted cases have been reported in literature in pure types of Friedreich's ataxia and hereditary cerebellar ataxia.

In hereditary optic-nerve atrophy, the atrophy accompanying skull deformities (tower-shaped skull, a hereditary affection) there is nothing in the perimetric findings which differs materially from a simple

primary optic atrophy. A progressive and concentric contraction of form and color fields is observed and central scotomata are frequently in evidence.

Embolism and Thrombosis of the Central Artery of the Retina.—Embolism and thrombosis of the central artery of the retina, or one of its branches, is a not unusual cause of simple atrophy. Fig. 74 illustrates the perimetric changes in this condition. In addition to the total loss of form and color fields in the area supplied by the occluded vessels, form and color fields in the apparently normal half are contracted. The ophthalmoscopic examination shows an optic disc apparently normal in its upper half, but pale and atrophic with contracted vessels in the lower half. This patient suffered from embolism of the inferior branch of the central artery of the retina.

Secondary Atrophy.—Secondary atrophy of the optic nerve is the form of atrophy which is observed after an injury to the optic nerve or other acute process which rapidly destroys the anatomical structure of the nerve. As a rule, ophthalmoscopic changes are only to be seen some time after the injury: for example, a blow on the skull is apt to cause this type of atrophy which may manifest itself only after the lapse of one or two months. It is a type of atrophy more apt to be unilateral than bilateral, but resembles primary optic atrophy in ophthalmoscopic findings and perimetrically. It differs from the primary variety in the greater contraction of the arteries and veins, in the chalky whiteness of the disc, and the less clearly defined edge of the disc. In either variety, in marked contrast to the postneuritic type of atrophy, the character of the inflammation is mild. In the early stages of either form, however, there may be evidence of congestion and of low-grade inflammation.

Perimetric findings are similar to those observed in primary optic atrophy. Concentric contraction of both form and color fields, with little disturbance of the central field other than rather rapid loss of

central vision, are the usual perimetric findings. Central and paracentral scotomata may be present. They are the exception rather than the rule.

Postneuritic or Consecutive Atrophy.—Postneuritic or consecutive atrophy is the type of atrophy observed following optic neuritis and choked disc. Preceding this form of atrophy, the usual symptoms of optic neuritis are present. The extent of the atrophy will be determined by the severity and duration of the optic neuritis. The dark room findings are in marked contrast to the simple varieties. The disc, as a rule, is of a dirty-gray color, and the details of the disc are obscured by the inflammatory exudate which fills in the cup. The outline of the disc is poorly defined.

Perimetric findings are less marked than one would expect, either in the inflammatory or in the regressive stage when atrophy is well established. In fact, it is a type of atrophy in which the prognosis is good, as compared to the primary and secondary types. Irregular contraction of form and color fields is most frequently observed. Large reëntering angles extending to the point of fixation are usual. If the inflammation occurs along the optic nerves, the chiasm or tracts, as in gumma of the base of the brain, the papillo-macular bundle may be involved, and central and peripheral scotomata, unilateral and bilateral, may be found.

It is interesting to note, however, that a neuritis and even a papilledema of marked severity may subside with comparatively little residual atrophy, and consequently with few perimetric changes in form and color fields. This is especially true of syphilitic optic neuritis if suitable treatment is instituted, and in pressure symptoms of tumor of the brain if decompression is practised reasonably early so as to relieve the intracranial pressure.

It is quite evident that disease along the course of the visual tract, from the eyeball to the primary optic centers, may produce an atrophy, either of the postneuritic or of the secondary type. Slowly developing

processes which gradually destroy the integrity of the nerve structure are usually followed by the secondary type of atrophy. On the other hand, processes which

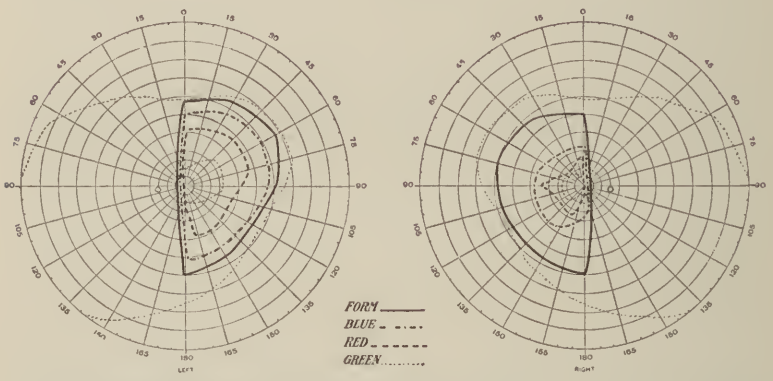


FIG. 109.—Bitemporal hemianopsia caused by gumma of the center of the chiasm.

excite a violent inflammation of the optic nerve, as a tumor of the brain pressing on or involving the visual tract, and at the same time large enough or so situated

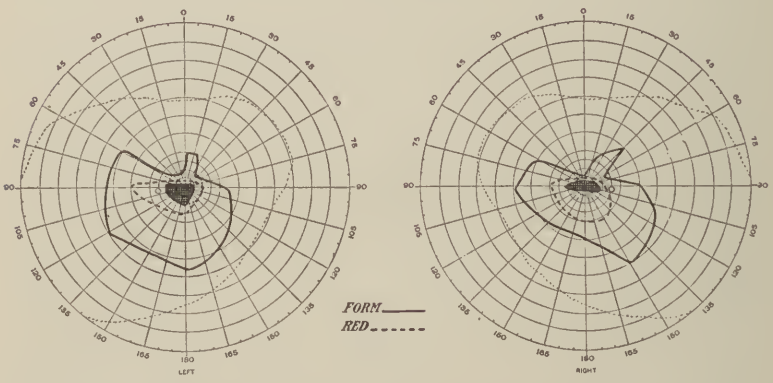


FIG. 110.—Altitudinal hemianopsia. Gumma of the under surface of the chiasm. Absolute central scotomata which later disappeared.

as to cause choked disc, may be followed by the post-neuritic variety. In the majority of instances a mixed type of atrophy is observed. Fig. 109 shows the field

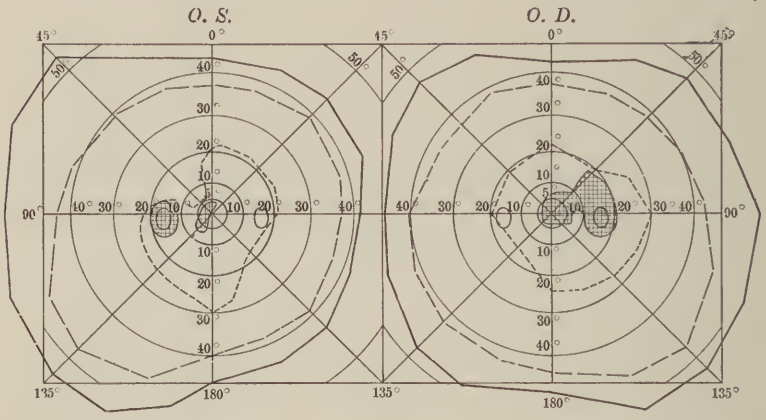
of a patient who suffered from a gummatous meningitis of the center of the chiasm. The discs in this case are white, edges are well-defined, arteries are contracted, and cribriform membrane is invisible because of the filling in of inflammatory exudate. Fig. 110 is the field of a similar case of gumma of the under surface of the chiasm, which gave rise to an altitudinal hemianopsia and an absolute central scotoma in each eye. The scotomata finally disappeared, leaving a permanent superior altitudinal hemianopsia.

Optic atrophy caused by disease of the chiasm and optic tracts posterior to the chiasm will be discussed more fully under Chiasmal and Optic Tract Disease.

Leber's Disease.—In Leber's disease, a familial atrophy, distinctive types of field changes are observed. Although grouped as an atrophy because consecutive atrophy is a terminal result, this disease primarily begins as a toxic inflammation of the ganglionic neuron of the retina. It begins as a rule between the years of fifteen and twenty, as an acute inflammation, almost fulminating in onset, patients becoming blind to all intents and purposes in the course of a few days to several weeks. The fundus shows marked pallor and there is gradual obscuration of the disc and fundus details. In the course of several months to a year, the symptoms abate; vision improves and the typical fundus picture of a postneuritic atrophy becomes visible. The disc is marked by extreme whiteness, is infiltrated and the disc margins are poorly defined. The disease is handed down as a rule to the male members of the family by a healthy mother, although females are not totally immune. In the group reported by the author before the Section on Ophthalmology, of the College of Physicians, Philadelphia, 1921, 2 occurred in females and 12 in males, 1 male having inherited the disease from his mother, who also suffered from the disease. Recovery is rarely complete, although few if any victims become totally blind.

The characteristic perimetric changes in the acute

stages are loss of central vision with peripheral contraction, sometimes amblyopia of the entire field.



Figs. 111, 112, 113 and 114.—Author's group of Leber's disease.

Fig. 111.—The mother, aged fifty-seven years, *O. S. V.*—6/9 F., *O. D. V.*—Macular loss.

When the patient has made a maximum recovery, a central scotoma, indistinct, relative, or absolute, is most characteristic. The blind area may involve

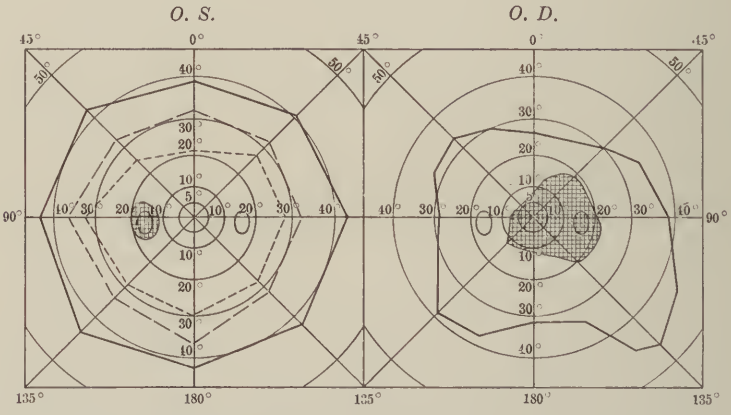


Fig. 112.—The son, aged thirty-seven years. A mental defective *O. S. V.*—6/22 *O. D. V.* Macular loss.

only the macula; it may be associated with an enlarged blind spot especially toward the macula, or the

scotoma may be cæco-central. The peripheral field rarely recovers its full normal limits. A contraction

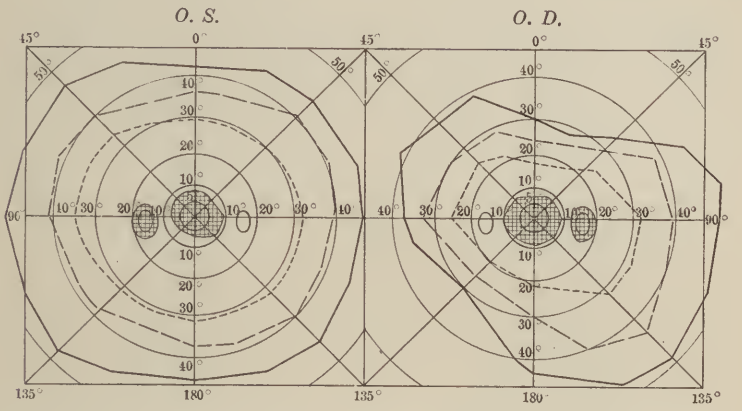


FIG. 113.—A brother of Case 1, aged fifty-two years. (2° Test object for form; 5° test object for colors.)

for form and color of varying but not of an unusually marked degree, is found to be a part of the perimetric picture.

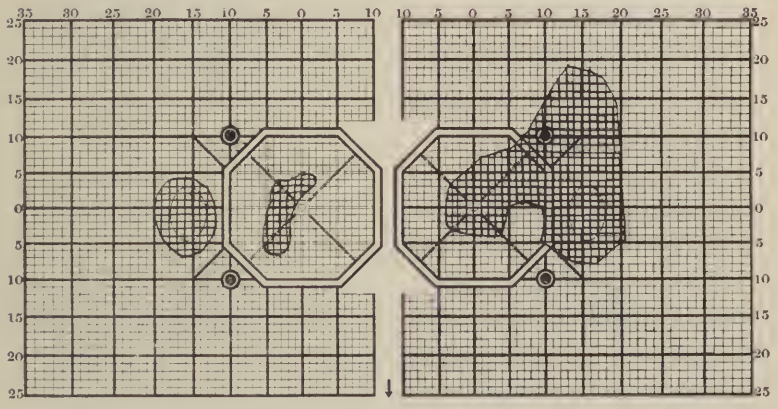


FIG. 114.—Central field studies made of Case 1, on the Lloyd slate.

In Figs. 111 to 114 are the fields of a group of cases reported by the author referred to above. Figs. 115 to 118 are groups reported by Posey.

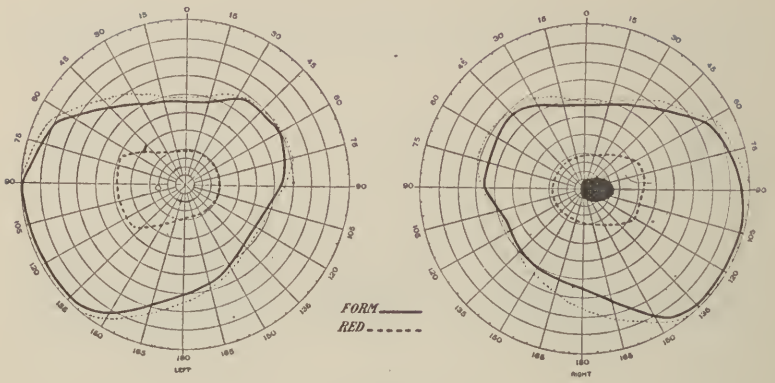


FIG. 115

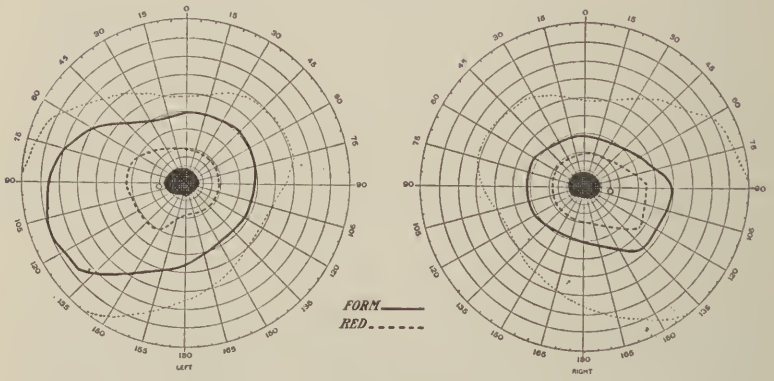


FIG. 116

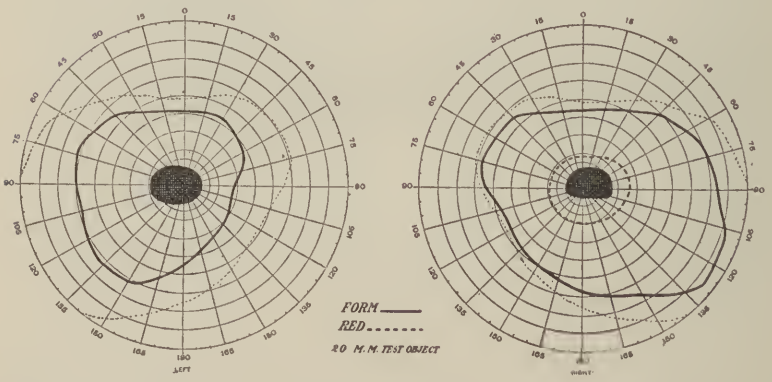


FIG. 117

FIGS. 115, 116, and 117.—A family group of Leber's disease. (Dr. Wm. Campbell Posey.)

In Posey's family group the heredity is not so characteristic, the patients being father and son, but the fields are especially characteristic. Form fields are normal in both cases, but color fields are reduced and there is a central scotoma in each case, absolute in the son and relative in the father.

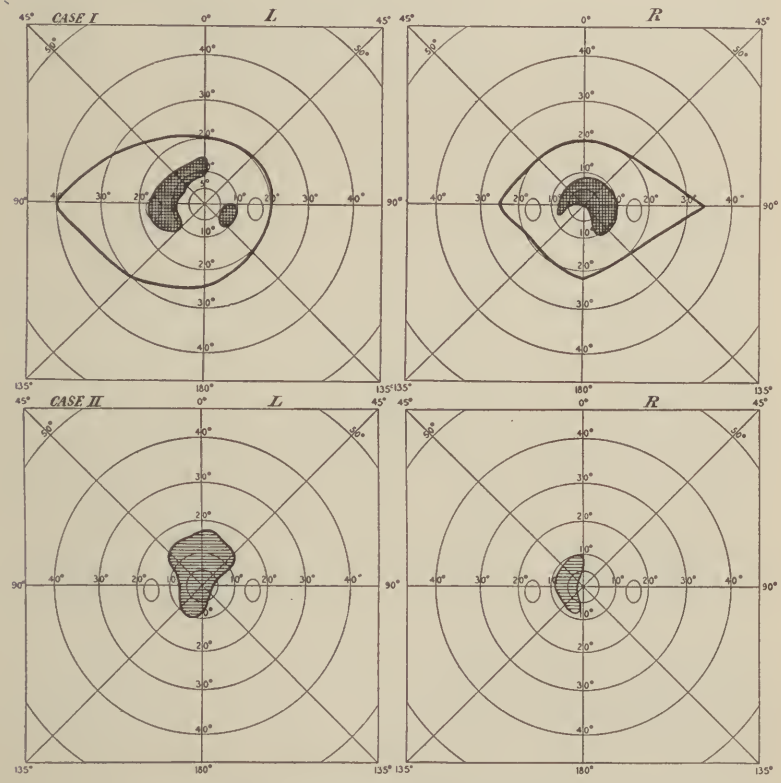


FIG. 118.—Second group of Leber's disease. (Posey.)

Optic Atrophy following Disease of the Choroid and Retina.—A fourth type of optic atrophy is that observed as a result of disease of the choroid and retina. Clinically, this type of atrophy resembles especially primary atrophy. The best example of this variety is seen in retinitis pigmentosa, and the most characteristic phase of the atrophy is a marked contraction of both arteries and veins.

The perimetric findings are those observed in simple optic atrophy with the addition of the field changes, which are characteristic of the primary disease. As disease of both retina and choroid is marked by central field disturbance, scotomata—central, peripheral and annular—this form of field change is constantly to be observed in the type of atrophy which follows disease of the choroid and retina. A most varied and irregular perimetric field is found and the changes due to the primary disease usually overshadow those of the atrophy.

DISEASE OF THE CHIASM.

Perimetric studies in disease of any part of the visual pathway have localizing value. In no part, however, are the findings so definitely localizing as in disease in and about the chiasm. A knowledge, therefore, of some of the more important structures immediately surrounding the chiasm, and likely to become the seat of disease, is quite as important as a knowledge of the anatomy of the chiasm in interpreting the perimetric findings incident to disease. Surrounded by the meninges, the chiasm rests above but not on the sphenoidal bone. Posterior to it is the infundibulum. In the sella turcica is the pituitary body and directly above is the anterior end of the third ventricle. To either side of the chiasm are the internal carotid arteries. Pathological changes in structure and function of the chiasm are usually the result of disease of one or more of the structures mentioned above.

In Figs. 119 to 124 are recorded the fields of a case of pituitary disease which was under the care of Drs. B. F. Devitt, Joseph Clothier, and Wendell Reber. So remarkable has been the course of this case that it is worthy of record.

At the onset, the special eye phenomenon was bitemporal hemianopsia. Five months later form fields had partly recovered under the use of thyroid and pituitary extracts. Color fields, however, remained

hemianopic. Under continued treatment, recovery was complete in about twenty months. A year later, however, the patient relapsed and altitudinal hemianopsia appeared in the right eye, with marked irregular contraction of the form and color fields in the left. Under the same glandular therapy, recovery was complete in eight months, and the patient has since then remained normal.

The unusual features are: (1) The bitemporal hemianopsia which gradually recovered under glandular therapy; (2) a relapse with the development of altitudinal hemianopsia, which again completely recovered under similar therapy.

In Figs. 125 to 130 are some of the variations observed in chiasmal disease of pituitary origin. They are selected from Cushing's interesting volume on *Pituitary Disease*, and are representations of the clinical types ordinarily observed. No part of the visual path however, is subject to greater variation from the average type of change than the chiasm, and fields bizarre and heterogeneous are a usual phenomenon when the chiasm is the seat of disease.

Luetic, tubercular, and traumatic meningitis are probably the most frequently observed, although disease of the pituitary body is also a common cause of chiasmal changes. Remote or proximal intracerebral lesions are often accompanied by distention of the third ventricle, which in turn may press upon the chiasm and produce types of hemianopsia. Cases of this kind have been reported. Less frequently, a bony exostosis has encroached upon the chiasm and sclerosis of the internal carotid arteries has been reported as an etiological factor in chiasmal symptoms.

The diagnostic perimetric symptoms of disease of the chiasm are bitemporal and binasal hemianopsia, irregular hemianopsias which may have begun or may terminate as one of these types, and the altitudinal hemianopsias. The chiasm is composed of crossed and uncrossed fibers. The relation of the position

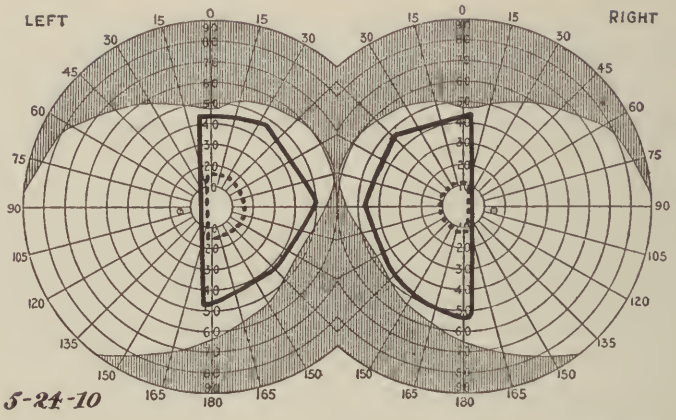


FIG. 119.—5–24–10, when first observed. Bitemporal hemianopsia.

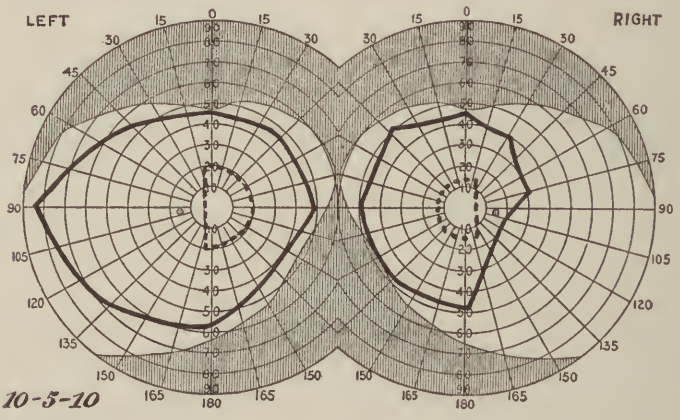


FIG. 120.—10–5–10, after treatment. Bitemporal hemiachromatopsia persisting.

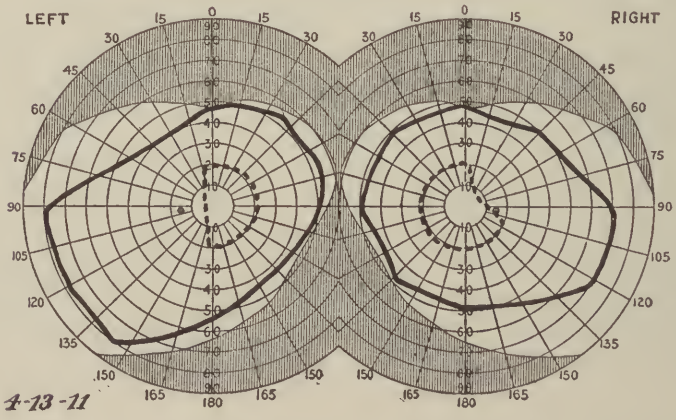


FIG. 121.—4–13–11, after treatment. Bitemporal hemiachromatopsia persisting.

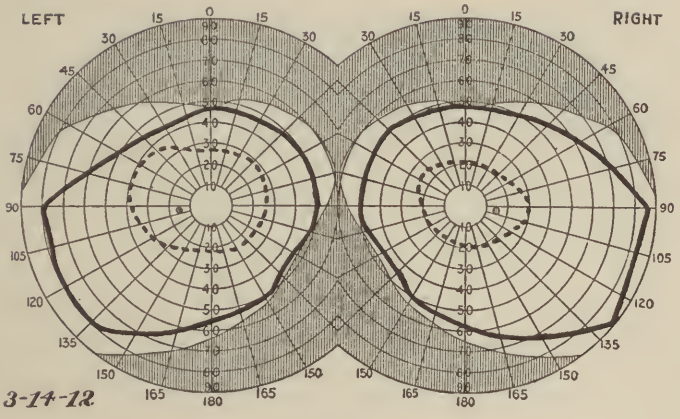


FIG. 122.—3–14–12, recovery.

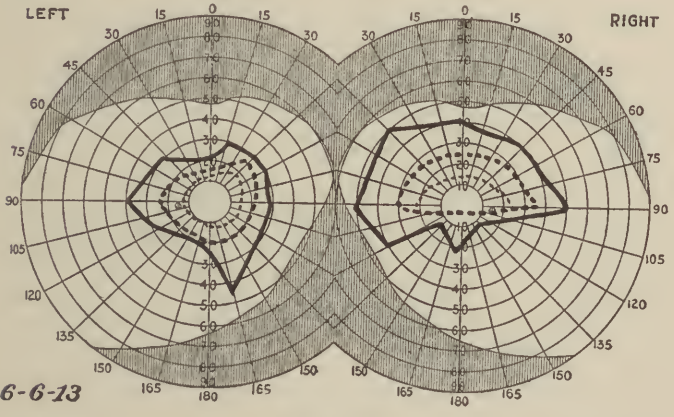


FIG. 123.—6–6–13, relapse with altitudinal hemianopsia in right eye

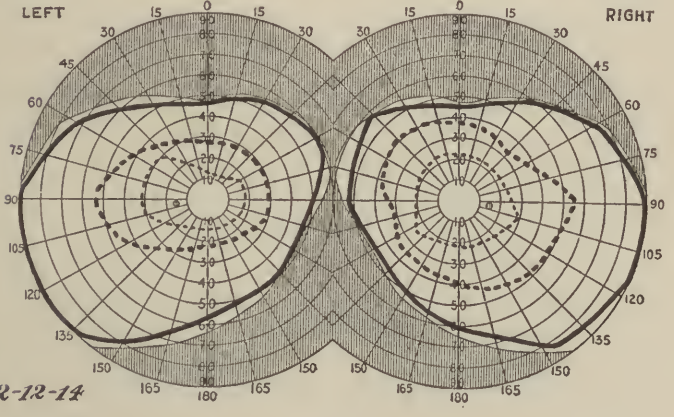


FIG. 124.—2–12–14, complete recovery under glandular therapy.

FIGS. 119 to 124.—Dr. B. F. Devitt's case of pituitary disease, cured by thyroid and pituitary extracts.

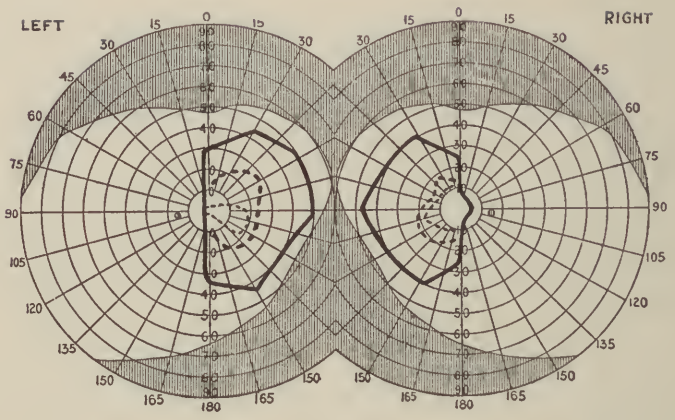


FIG. 125.

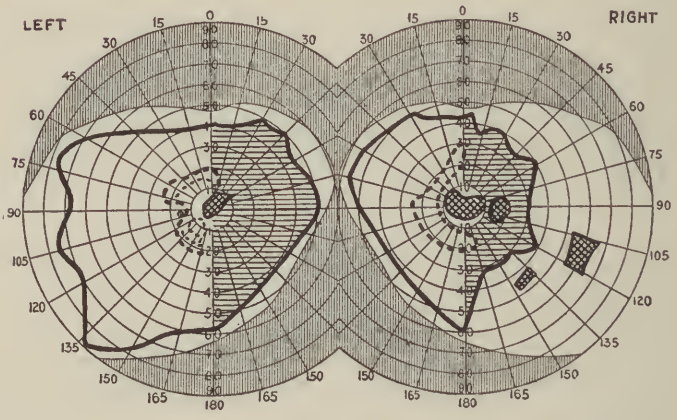


FIG. 126.

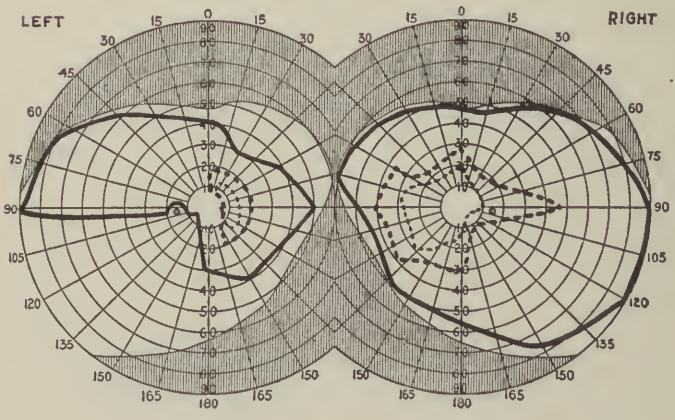


FIG. 127.

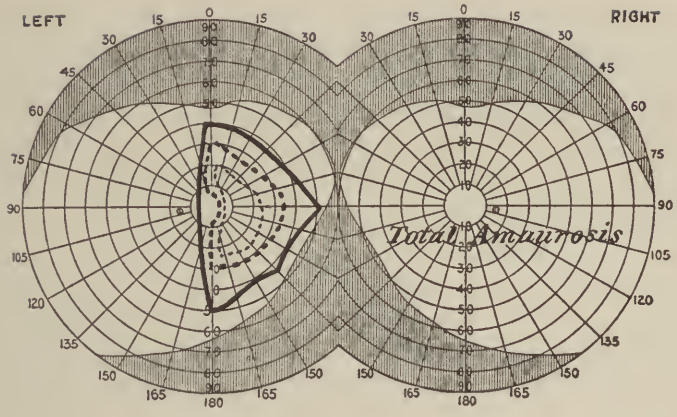


FIG. 128.

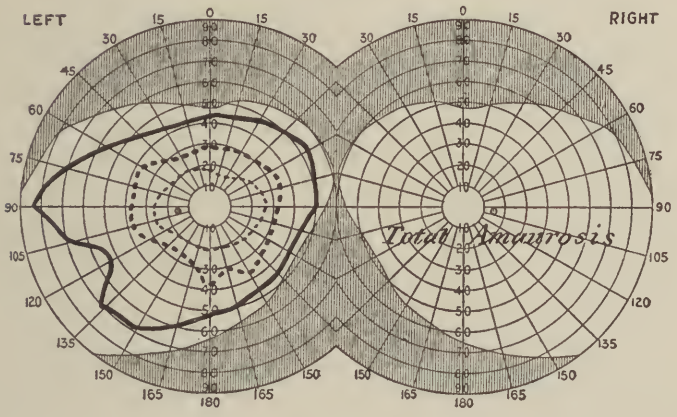


FIG. 129.

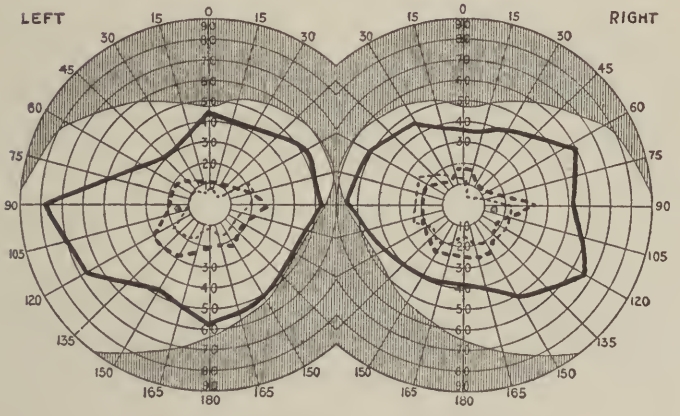


FIG. 130.

FIGS. 125 to 130.—Field changes observed by Cushing in pituitary disease.

of the nerve fibers in the chiasm, as well as in the optic nerves and tracts, to the various quadrants of the retina, has been established. The nerve fibers of the under surface of the chiasm are associated with the ganglionic layer of the inferior retinæ, and the upper part of the chiasm with the superior retinæ. In a similar manner, the outer or uncrossed fibers proceed from the temporal halves of the retinæ and the middle or crossed fibers proceed from the inner halves of the retinæ. If the chiasm is completely severed anteroposteriorly the crossed nerve conductivity is entirely destroyed, the inner halves of both retinæ become blind, and the type of hemianopsia known as bitemporal hemianopsia will be the perimetric finding. The temporal fields in each eye will be totally blind. In any complete form of half-vision, the dividing line between the seeing and the blind part of the retina may be one of several types. A fairly straight line may be found passing through and including the macula, as in Fig. 44. More frequently, however, the macula escapes, as in Fig. 46. In other cases, beginning back of the chiasm, not only the macula escapes, but also an area above and below the macula toward the periphery of the field will be found intact, as shown in Fig. 47. This condition is spoken of as an overshot field. A fourth variation is that shown in Fig. 45, in which the dividing lines are oblique rather than straight. The two latter conditions are attributed to differences in anatomical distribution of the crossed and uncrossed nerve fibers in different individuals.

The dividing line for color is practically the same as that for form in a complete hemianopsia. In a slowly developing case, however, color may, and in all probability will, progress more rapidly than that for form, as color changes are the earliest evidence of optic-nerve atrophy. (See Fig. 108.)

Less frequently observed is the pure type of binasal hemianopsia of chiasmal origin. Two lesions are necessary to produce this type of field. The chiasm

must be affected or pressed upon on both sides to produce the condition. Isolated instances of advanced sclerosis of the internal carotid arteries have been found at autopsy in cases which during life presented this form of hemianopsia. Inflammatory processes about the chiasm, in which the center of the chiasm escapes, might be responsible. Cushing has observed this form of hemianopsia in a number of cases of pituitary disease. The condition is relatively rare as a clinical phenomenon.

Bilateral altitudinal hemianopsia is usually of chiasmal origin and occurs more frequently than text-

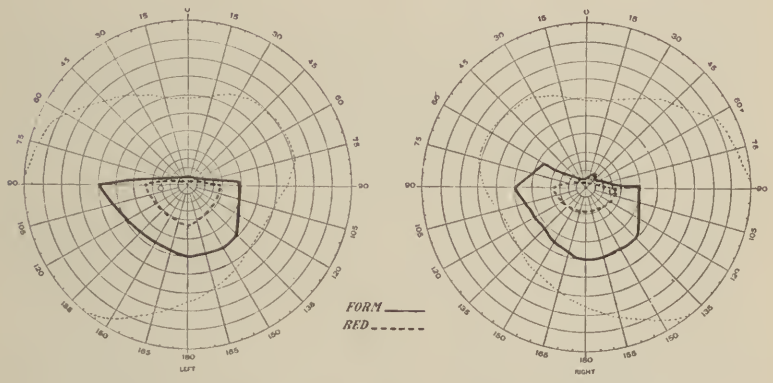


FIG. 131.—Altitudinal hemianopsia. Gumma of the chiasm.

books and literature would seem to indicate. Figs. 110 and 131 are the fields of a case of superior altitudinal hemianopsia which the author had under his observation for a number of years. In Fig. 110 the disease was at its height, and Fig. 131 was the final result. It was due to a gumma of the inferior part of the chiasm. These forms of altitudinal hemianopsia are peculiar to the chiasm or parts of the visual tract close to the chiasm. They occur in no other parts of the visual tract, unless there are very unusual symmetrical bilateral lesions. A tumor of the central part of the cerebellum, pressing upward equally on both cuneiform bodies, might cause an irregular form of bilateral

superior altitudinal hemianopsia. Such a condition, however, must necessarily be exceedingly rare. (See Fig. 141.)

Types of complete chiasmal hemianopsia under discussion are less frequently observed than incomplete and irregular forms. For example, a lesion located in the center of the chiasm will give rise to bitemporal hemianopsia. If, however, the process begins or develops a little to the side and back of the chiasm, involving the optic tract, homonymous hemianopsia of the right or left half of each retina will be found. If the process develops in the direction of the chiasm, the crossed fibers going to the opposite side of the brain may be destroyed, and the patient will therefore have a totally blind field in the eye on the side of the lesion and a blind temporal field in the opposite eye. In a similar manner, a lesion in the center of the chiasm may extend to the right or left and produce, in addition to the bitemporal hemianopsia, total blindness in the eye to the side toward which the disease extends. (See Fig. 128.) A lesion beginning at the outer side of the chiasm, giving rise to half-blindness (nasal) in the eye on the same side as the lesion, may rapidly develop into total blindness in one eye, if the lesion extends forward so as to destroy the optic nerve. If it extends back and involves the entire tract, homonymous hemianopsia will develop. If it involves the chiasm and destroys both crossed fibers as well as the uncrossed on the side of invasion, there will be total blindness in one eye and temporal blindness in the contralateral eye. Inasmuch, therefore, as the chiasm is small and inflammatory processes irregular, these mixed types of hemianopsia are more frequently observed than the pure chiasmal hemianopsia. (See Figs. 125 to 127.)

When the cause of commissural change is disease of the pituitary body, nerve changes are slow in making their appearance because the nerve fibers readily adjust themselves to the slowly developing tumor

formation. The earliest symptom may be a shrinking in the upper outer quadrant of one or both fields. Color changes, as a rule, precede form, and a fairly well-defined color hemianopsia may be established before

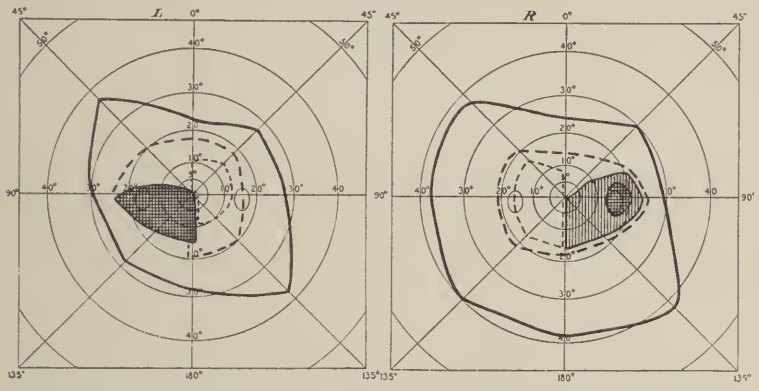


FIG. 132.—Right and left fields of a case of gumma of the upper part of the chiasm. Bitemporal inferior quadrant anopsia, absolute in the left eye, relative in the right. Bitemporal hemianopsia for green.

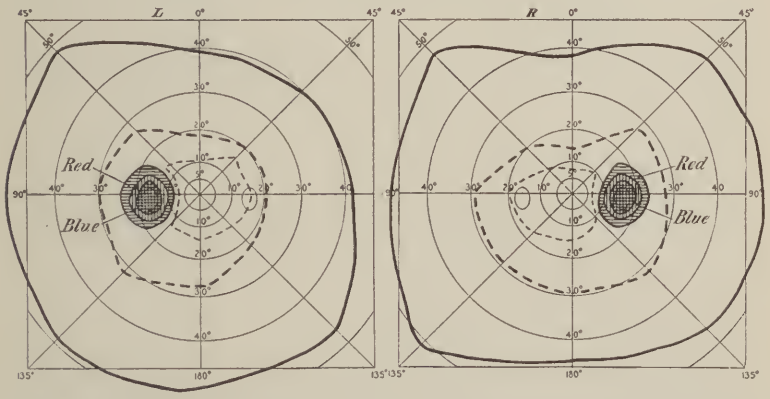


FIG. 133.—Fields taken one week after Fig. 132. Patient under anti-syphilitic treatment. Hemianopsia for green gradually disappearing. Absolute enlargement of both blind spots, greater enlargement for blue, and largest for red.

a change in the form field is noted, or only a moderate contraction of the upper, outer quadrant is in evidence. Bitemporal color hemianopsia, or beginning contraction of the upper, outer quadrants for form and color,

are therefore suggestive of beginning commissural invasion, and careful studies of the commissural region should be made by the roentgenologist in such cases.

Central amblyopia is noted as a symptom of pituitary and other perichiasmal disease. It may be of a fleeting character, unilateral or bilateral, or it may mark the beginning of a central scotoma. It is a well-known fact that the papillo-macular bundle is more susceptible to toxic and organic influence than other parts of the nerve, and disease about the chiasm is no exception to the rule. Central scotomata may be an early or late phenomenon, or as in many instances, totally absent.

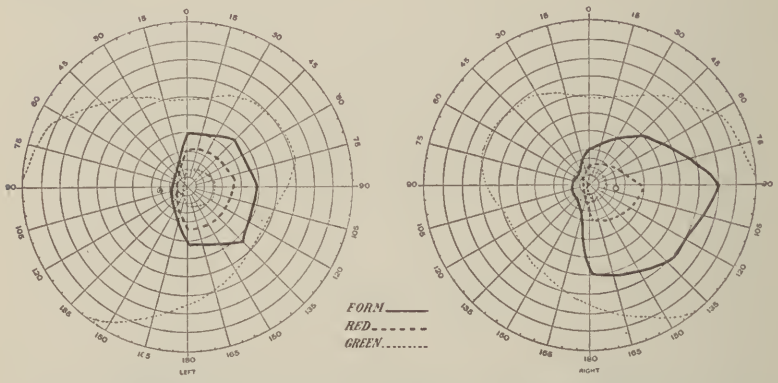


FIG. 134.—Left homonymous hemianopsia. Hemorrhage into right optic thalamus. Fundus changes slight. Fields taken five months after onset. Pain in paralyzed arm and leg severe.

Atrophy of the optic nerve is visible, as a rule, although tardy in disease of the chiasm. Field changes are therefore not limited to the hemianopic blind areas, but contraction for form and colors in other parts of the field will be frequently observed. Disease due to the extension of the pathological process to all parts of of the chiasm, and bizarre types of fields, will occasionally render a diagnosis difficult in the absence of other clinical evidence.

It is also possible to find a hemianopic field complicated by hysteria. In such instances, in addition to the hemianopsia, is added the evidence of hysteria

in the non-hemianopic part of the field. This complication is not a remote possibility, but an actual occurrence. It is a matter of common observation that patients afflicted with chronic intracranial disease very often are the victims of hysteria; and the influence of frequent neurological and ophthalmological examinations does not tend to diminish the hysteria. With no tendency, therefore, to wilfully distort perimetric fields, but controlled by an influence which can only be expressed by inhibition, the most bizarre and heterogeneous types of fields may be developed from time to time. Unless the hysterical complication is recognized, such fields will not only be misleading, but will be of absolutely no value.

Similarly, a tumor or new growth pressing upon the chiasm directly or indirectly and large enough or so located as to produce choked disc or papillitis may cause hemianopic fields plus changes in the balance of the field incident to these conditions.

Field Changes in Pregnancy.—During the last few years, attention has been drawn to changes in the visual field which occur during pregnancy. Finlay, of Cuba (Transactions of An International Congress of Ophthalmology, 1922), claimed that he found bitemporal contraction in a large number of pregnancies. The same claim was made in discussion of this paper by Drs. Maud Carvill and Walter Lancaster, of Boston. The changes observed were attributed to alterations in the pituitary body which occur during pregnancy. From this and other contributions which have appeared in literature, it is probable that alterations of a chiasmal type may occur in a certain number of cases. In fact, the increase in the size of the pituitary gland during pregnancy has been reported to occur in a sufficient number of cases to warrant the claim of Finlay that visual field changes may be observed. Further studies, however, will be necessary, with due consideration for preëxposure, surrounding field, and other standards in technic, before a definite type of field can be claimed as peculiar to this condition.

FIELDS IN DISEASE OF THE OPTIC TRACTS AND PRIMARY OPTIC CENTERS.

Optic atrophy which eventually becomes visible by means of the ophthalmoscope is a characteristic feature of disease of any part of the visual pathway between the eyeball and the basal nuclei. Disease of the nuclei is also accompanied by atrophy. The closer the focus of disease to the eyeball, the more rapid is the appearance of the atrophy in the nerve head. Disease of the tract, however, is distinguished from disease of other parts of the visual path anterior to the tract by hemiatrophy and by hemianopsia. Atrophy as a rule, is incomplete and is confined to the half of each nerve head on the side of the lesion.

Perimetrically, the atrophy manifests itself by homonymous hemianopsia on the side opposite to the lesion. As in other parts of the visual path, color hemianopsia may precede or progress more rapidly than that for form. The hemianopsia usually is complete, excepting in those cases in which the pathological process is either very slow in developing or becomes arrested spontaneously, or under the administration of proper therapeutic measures. Unlike commissural hemianopsia, unless the case is complicated by increased intracranial pressure, causing either a papillitis or choked disc, or by hysteria the field changes are sharp and limited to a right or left half-vision. In the seeing parts of the retina, fields of normal dimensions, both for form and color, may be found. The maculæ are usually intact, as in chiasmal hemianopsia, and the variations of the dividing line mentioned in chiasmal hemianopsia are especially well exemplified. Complete hemianopsia is the rule, because of the compactness of the bundle of nerve fibers which make up the optic tract. A hemiatrophy, therefore, which is visible by the use of the ophthalmoscope, accompanied by a homonymous form of hemianopsia, is pathognomonic of disease of the tract.

For a time the value of the Wernicke pupillary

phenomenon and the Wilbrand prism experiment, as aids in differentiating between hemianopsia above and below the primary optic centers, was in doubt. Studies by Hess and Clifford Walker raised the question of doubt in the minds of many. The present consensus of opinion, however, is that the uncertainty is practically one of improper technic in eliciting the symptom. With proper technic the Wernicke pupillary inaction has been observed by careful observers with sufficient frequency to warrant its inclusion as a differentiating symptom of value.

LESIONS OF THE PRIMARY OPTIC CENTERS.—*External Geniculate Body, the Anterior Corpus Quadrigeminum, and the Tail of the Thalamus—the Pulvinar.*—It is most difficult to discuss lesions of the primary visual centers without including the internal capsule. Reference to Fig. 135 will more graphically help the reader to visualize the ultimate relations than a most careful word picture. A neoplastic growth or a vascular lesion in and about these centers is apt to produce associated pressure symptoms as for example, hemiparesis, hemianesthesia and hemianopsia, all of which may be complete or imcomplete, temporary or permanent. A careful study of the hemianopsia, its progress, and especially its completeness, and the *associated symptoms* must be our guide in determining the exact location of the lesion in homonymous hemianopsia. Visible optic atrophy and the Wernicke pupillary phenomenon are of great value.

Fig. 107 shows a field of a case of homonymous hemianopsia which occurred in a recent hemiplegic. The patient was referred to Dr. Reber's Clinic in the Polyclinic Hospital by Dr. John Rhein, with a diagnosis of hemorrhage in the neighborhood of the optic thalamus. This area was suggested by Dr. Rhein as the probable seat of the lesion because of the marked pain in the paralyzed extremities. The condition of the nerve head in this case is doubtful, but fields are conclusive of disease in the neighborhood of the optic thalamus probably involving the internal capsule.

A similar case under the author's care shows the same phenomena, a left-sided hemiplegia preceded by left hemianesthesia, left homonymous hemianopsia and conjugate deviation of the eyes to the right, with

FIG. 135.—Diagram showing the position and the relations of the visual fibers in the posterior limb of the internal capsule. *C*, caudate nucleus; *L*, lenticular nucleus; *T*, optic thalamus; *A L*, anterior limb of internal capsule; *F*, *H*, *A*, *B*, motor fibers in the anterior two-thirds of the posterior limb; *S*, sensory fibers in the posterior third of posterior limb; 1, 2, 3, 4, corona radiata; *a*, fibers to temporol lobe: *v*, optic radiation.

marked pain in both arm and leg. Optic atrophy is not visible by means of the ophthalmoscope. The lesion in this case is probably in the neighborhood of the internal capsule, involving the pulvinar.

Of the primary optic centers, the external geniculate

body is in direct communication with the cortico-visual centers in the cuneus. While visual fibers pass to the anterior corpus quadrigeminum, the fibers from this center pass to the nucleus of Edinger and Westphal of the oculomotor nerve to complete the reflex arc which permits of contraction of the pupil when light is thrown upon the retina. Lesions, therefore, of these centers must necessarily produce definite symptoms and in addition associated symptoms from pressure phenomena. The thalamus is frequently the seat of vascular disease in middle and late adult life, and because of its size is especially apt to be associated with pressure symptoms.

Other concomitant symptoms of a hemianopsia due to a lesion in this area are hemianesthesia, hemichoreiform and athetoid movements, etc. A case in point, Fig. 140.

Illustrative of a lesion in this same general area, but a little further back without involvement of the primary optic centers, are the fields show in Figs. 136 and 137. The fields in Fig. 136 are incomplete quadrantic fields which were the result of a vascular lesion. The patient, a man aged twenty-eight years, became confused, had a sense of numbness in left arm and leg with motor weakness of the left leg and some thickening of speech. The attack disappeared in about an hour, and only the visual disturbance remained. This quadrantic defect has remained although the patient has fully recovered and now is in good health. The condition was the result of overwork—a subnormal vascular tension and a weakened myocardium.

Fig. 137 are the fields of a young man of about thirty years of age, who suffered from migraine. Similar to the case just cited, there was a sudden confusion of thought, thick speech, a tingling of the left side with left-sided motor weakness, all of which passed off after a time, the visual defects alone remaining. In both patients, the motor involvement clearly placed the lesion well forward either in the region of the internal capsule or in the beginning of the optic radiation. In

the first case, the motor weakness was limited to the left leg, the hemianopsia was quadrantic, and the anes-

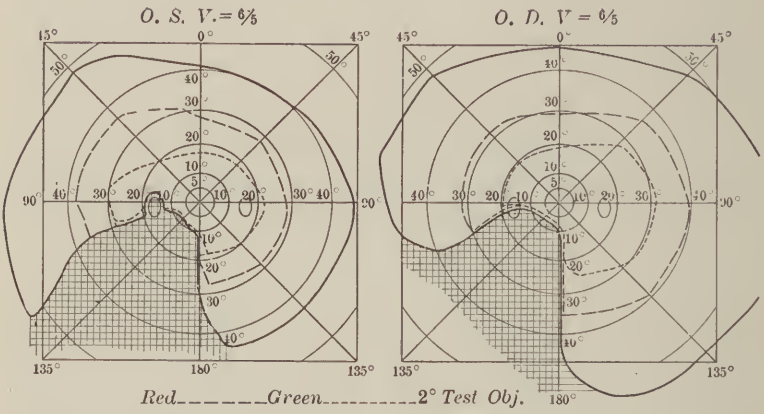


FIG. 136.—Left inferior homonymous anopsia (quadrantic) due to a vascular lesion in region of internal capsule.

thesia a left hemianesthesia—a group of symptoms which are quite definite in localization.

Homonymous Central Amblyopia.—Amblyopia, a symptom which is observed as a temporary phenomenon

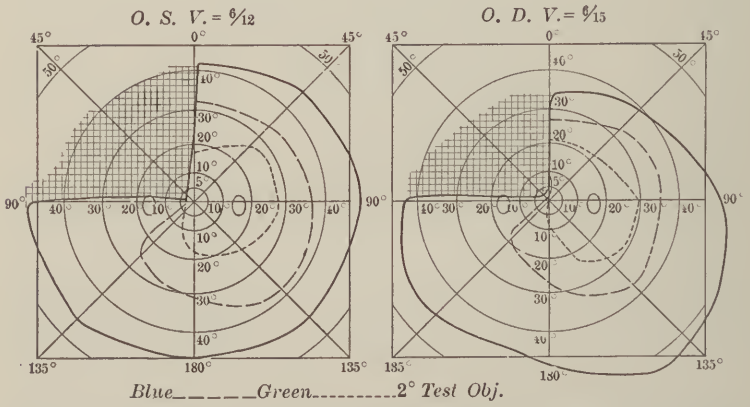


FIG. 137.—Left superior homonymous anopsia (quadrantic) associated with migraine.

of commissural disease, and occasionally the beginning of permanent scotomata, is a more constant symptom

in disease of the internal capsule, although not so frequently observed here as in disease of the optic radiation and the region of the calcarine fissure. After the onset of the central amblyopia which is bilateral and complete, there is a partial restoration of the halves of central vision which are represented by the macular centers on the opposite side of the lesion. In other words, the amblyopia becomes a hemianopic amblyopia of the homonymous type. This symptom, however, is especially observed in disease of the cortex. Its presence argues for a separate pathway for the papillo-macular bundle from the macula to the brain cortex.

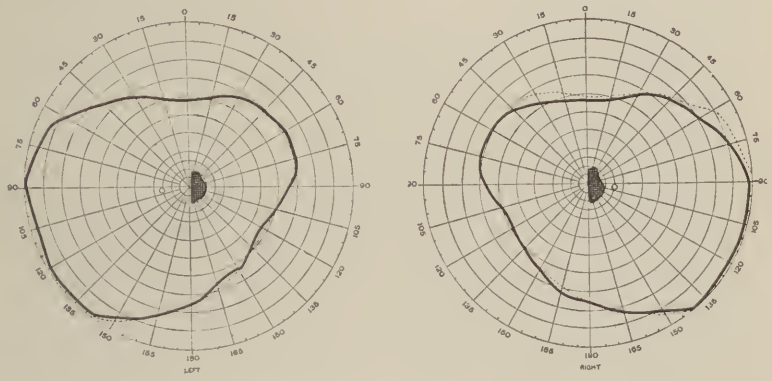


FIG. 138.—Hemiamblyopia of central origin. (Posey.)

It is interesting to note that in the cases reported, central vision may be good for distance, but the defect is manifest at the near point. This is especially true when the hemianopic scotomata are to the right. (See Overshot Fields.) Wilbrand has pointed out that in reading, the minute details of the letters are necessary, whereas distant vision may be maintained with a considerable central defect.

Posey's case,[1] is of great interest in this connection. Briefly, the history of the case is as follows: A man, aged fifty-six years, a victim of rheumatoid arthritis,

[1] Some Unusual Changes in the Visual Field, Jour. Am. Med. Assn., May 8, 1915, vol. 64.

suffered from sudden confusion of mind, dizziness, and disturbed speech. These symptoms cleared away after several days, when the fields in Fig. 138 were taken. Form fields remained normal, but small absolute paracentral scotomata to the right remained, and persisted until the patient's death from apoplexy a year later. As in other cases, the maculæ were probably totally involved at first, but his mental condition prevented the demonstration of the same perimetrically. After his mentality became normal, the scotomata were homonymous in type. These fields are remarkable, as one rarely can demonstrate perimetrically the presence of central hemiamblyopia of the homonymous type.

Disease of the Optic Radiation and Visual Centers in the Occipital Cortex.—Until the outbreak of the late war, the interpretation of visual field changes in lesions of the visual cortex and in the optic radiation was rather vague and in many instances hypothetical. Complete studies with postmortem and pathological findings were not made in sufficient numbers to draw dependable conclusions. The abundance of material, however, contributed by fatalities incident to trench warfare furnished the opportunity of confirming many correctly conceived ideas, and at the same time has corrected errors in cerebral localization. Although the lesions were almost exclusively traumatic in character, and most of the studies were necessarily made with undue haste, the wealth of material enabled those who were scientifically inclined to gather much valuable information. It would be difficult indeed to mention the names of all who have thus contributed to the sum-total of our knowledge gathered during the last eight years, but the names of Holmes, Lister, and Morax stand out preëminently as voluminous contributors. In addition to the contributions from the war, the wonderful work of men in civilian practice during this same period has contributed not a little to the exactness of knowledge which previously was without confirmation. Notably

in this group should be mentioned the name of Cushing. A third factor is the emphasis which has been placed on the so-called quantitative methods of perimetry in which Sinclair, Walker, Traquair, and others have led the way. It is in this particular type of field studies that the quantitative method is most fittingly adapted, not to the exclusion of the qualitative method but supplemental to it. In fact, it has been a question in the author's mind as to whether quantitative tests for form, if properly applied, may not uncover slight form defects in the periphery in certain cases in which only types of achromatopsia or dyschromatopsia are found, and form defects are recorded as absent.

Special Characteristics.—In a general way the essential differences between hemianopsia due to lesions above the primary centers, and those due to tract and primary visual center disturbances are fourfold: (1) The Wernicke pupillary phenomenon is absent; (2) atrophy visible in the nerve head is not in evidence; (3) instead of complete forms of homonymous hemianopsia, the hemianopsia takes the form of irregular homonymous anopsia, with a tendency finally to a total loss of half-vision; (4) the preservation of the macular area.

1. The Wernicke phenomenon was discussed in "Tract Diseases" and needs no further amplification. If properly tested, its absence, *i. e.* normal response, argues for a lesion above the primary centers.

2. The absence of atrophy is of much diagnostic value in chronic cases. In lesions of the visual cortex atrophy has been traced down to the primary basal centers, but it has not been recognized in the nerve head by means of the ophthalmoscope. It must not be forgotten, however, that tumors in the posterior part of the brain and especially beneath the tentorium are apt to be accompanied by choked disc. This in time may cause consecutive atrophy. Its presence may, therefore, obscure what otherwise might be a pure type of hemianopsia of the radiation or cortex. If present,

in addition to the hemianopsia of the homonymous type, the retained visual half-fields would also show changes due to the residual atrophy of choked disc.

3. The hemianopsias, as a rule, are only partial, but may gradually enlarge until all but the half macula or even that is involved, although more frequently not only the fixation center but an area from five to ten degrees beyond the fixation point may be preserved. To the macular preservation we will return later. The reason for this incompleteness is to be found in the breadth of the expansion of the optic radiation. In the tract, it was pointed out, the active visual path was limited to a comparatively compact bundle of nerve fibers. In the optic radiation, there is an expansion of the fibers[1] which divides the radiation into dorsal, lateral, and ventral bundles. The ventral fibers, according to this writer, reach their destination by a long detour around the lateral ventricle. After a somewhat extensive looping in the temporal lobe, the occipital visual fibers are again gathered together into a compact bundle according to Henschen[2] 5 to 10 mm. vertically and 2 to 3 mm. thick, at the posterior horn of the lateral ventricle. This broad expansion, therefore, makes it possible for a small lesion to include only a part of the radiation. As the lesion increases in size, more and more fibers become involved until the hemianopic process is complete. If the pathological process involves the posterior visual pathway by extension or by compression, partial hemianopsia is of even more frequent occurrence. Studies, however, must be made early in order to demonstrate the tendency to partial hemianopsia.

Asymmetry of the homonymous fields is a symptom which is said to be of common occurrence in lesions in the temporal and occipital lobes. Cushing laid special emphasis upon this feature of the clinical cases which he reported before the American Neurological Society in 1921. The symptom has so frequently been observed

[1] A. Meyer: Tr. Assn. Am. Phys., 1907, **22**, 7.

[2] Handbuch der Neurologie, vol. **1**, pp. 903–914; vol. **3**, p. 773.

in disease of this part of the visual cortex, that it deserves discussion at greater length.

In the same connection the sloping tendency of the dividing line, before it reaches the cortex and becomes complete, has been alluded to as rather characteristic of visual disturbance in the radiation in contrast to its less frequent occurence in tract disease. This, too, finds its explanation in the greater extent of the radiation when compared to the compact tract bundle. Furthermore, the tract is open to damage by basal inflammations, perhaps more frequently than from tumor formation, a rapid process. The radiation, on the other hand, is more apt to be damaged by tumors although vascular lesions are also common.

A few cases of complete loss of both fields with preservation of the maculæ have been reported. One, reported by Bromwell,[1] is most interesting because the condition persisted for twenty-seven years and finally came to autopsy. The patient had tubular vision of central origin—a rather unique phenomenon. A traumatic case reported by Scarlett and Ingham,[2] is recorded in Fig. 139.

Hemiamblyopia of central origin is equally rare. It is a frequent temporary symptom in pituitary diseases, and in chiasmal lesions may mark the beginning of permanent scotomata. In lesions farther back in the visual pathway the symptom is rare. Several cases due to injury of the tip of the occipital lobe have been reported. In this connection, the case reported by Posey[3] is of unusual interest, Fig. 138.

An associated symptom of cerebral types of anopsia, and helpful in locating the lesion, is disturbance of the concept center known as mind-blindness. Meyer, in the studies of the optic radiation, observed that the three bundles of filaments which make up the geniculocalcarine path remain of fairly uniform thickness throughout. This suggested the improbability of

[1] Edinburgh Med. Jour., July, 1915, p. 47.

[2] Arch. Neurol. and Psychiat., 1922, **8**, 225–245.

[3] Some Unusual Changes in the Visual Field, Jour. Am. Med. Assn., May 8, 1915, vol. **64**.

fibers from these fasciculi passing to the angular cortex. The fact remains, however, that certain lesions in the occipital lobe intercept the communication of the

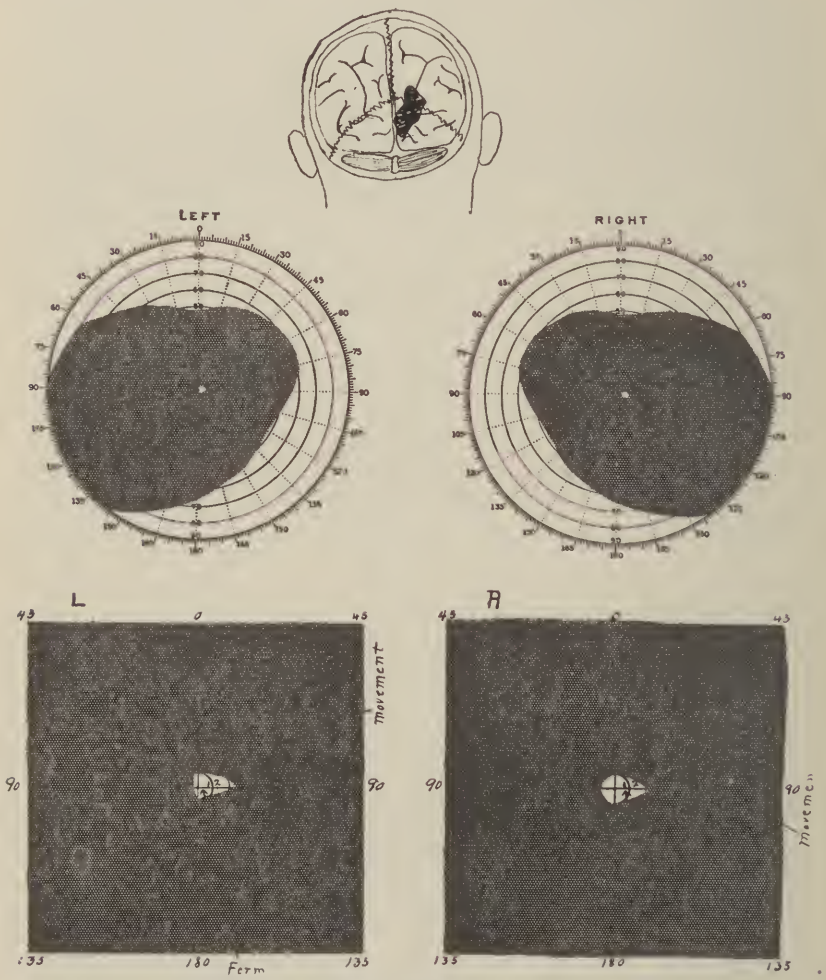


FIG. 139.—Right occipito-parietal wound and defect. Complete left hemianopsia; incomplete right hemianopsia. Perimeter charts. (Scarlett and Ingham.)

angular gyrus, and the calcarine cortical centers, with the result that mind-blindness and other symptoms appear.

4. The fourth and last general difference between tract disease and pathological invasion of the radiation

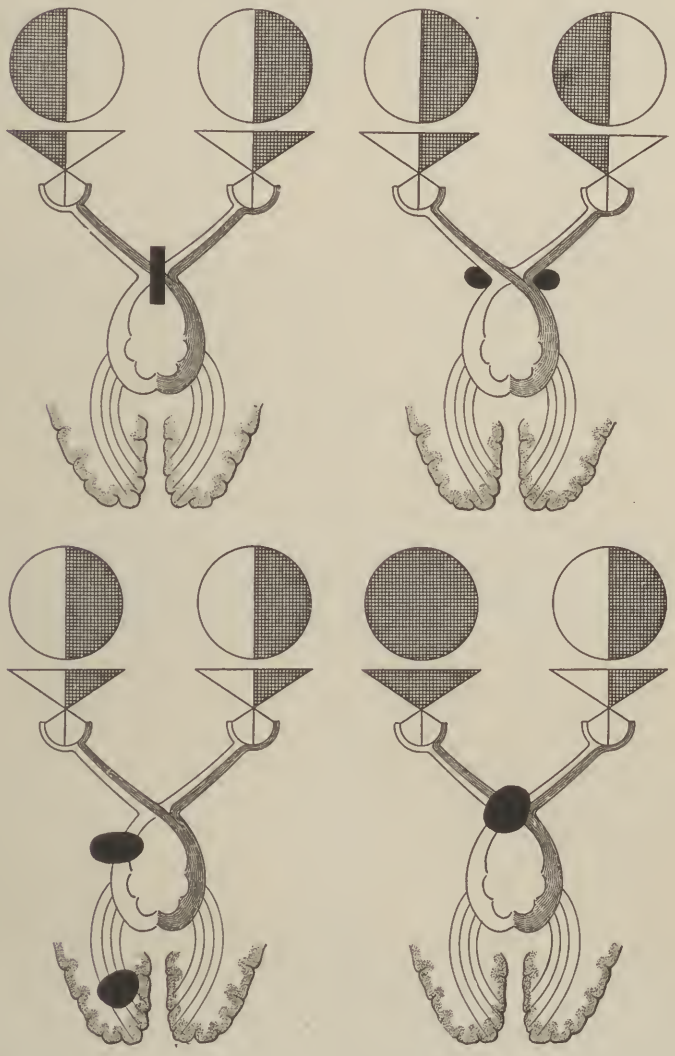


FIG. 140.—Diagram showing field changes in lesions of different parts of visual path. (After Mills.)

is the sparing of the macula in the latter. In chiasmal and tract lesions, the dividing line of the hemianopsia

as a rule passes through the fixation point or escapes it by a very narrow margin. In disease of the radiation and in cortical lesions, not only the fovea centralis but the entire macular area commonly escapes. While of much importance as a clinical fact in this connection, the reason for the same will be better understood in the discussion of visio-cortical disturbances. It is a symptom common to lesions above the primary centers and serves as a link in differentiating it from hemianopsia due to tract disease.

In addition to the four points enumerated as general points of difference in the visual phenomena found in homonymous hemianopsia, there are a number of clinical symptoms peculiar to each type of half-vision which when present will help materially in locating the lesion. They are not, however, germane to visual field studies in this connection.

Color Anopsia.—Hemiachromatopsia and hemidyschromatopsia have been recorded in literature without evidence of change in the form field. They have been found in the central and in peripheral corresponding areas, incomplete as in the form field, or as complete color hemianopsia. So far as we know, thus far special fibers or tracts for colors have not been isolated. Some of the cases recorded as color half defects without form changes are without doubt correct. Until recent years, however, or previous to the introduction of quantitative methods and especially of the more painstaking qualitative methods, many early form changes escaped detection. On the other hand, color changes are the earliest and most sensitive and in early physiological block only color defects may be found. To rely on quantitative perimetry alone may fail to uncover what is clearly demonstrable by good qualitative technic. They are complemental methods of study, and neither should be ignored. In a majority of cases color fields are most important. Color hemianopsia may be complete, although a fairly large form field is yet responsive to even minute white stimuli.

This is particularly true in regressive stages after operation. In the presence of color defects, one should clearly differentiate between true color disturbances or the inability to see colors and *color amnesia*—inability to name the colors, which the patient may recognize and perceive correctly.

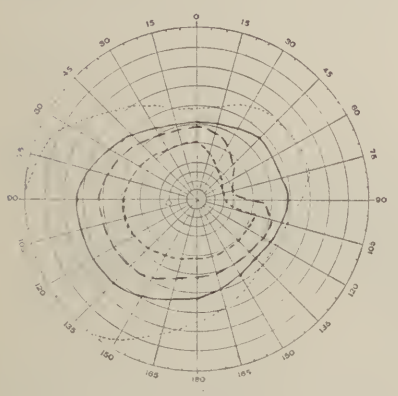


FIG. 141 *a*

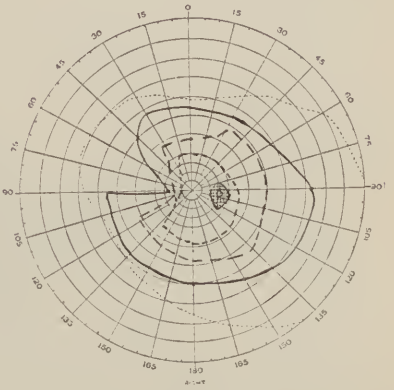


FIG. 141 *b*

FIG. 141.—Binasal quadrant anopsia in a girl, aged sixteen years, due to an inflammatory process in the posterior cranial fossa. Bilateral choked disc of 7 diopters. A general improvement followed a subtentorial decompression. The Wassermann was positive. 1° Test object. ————Form; — —Blue; — — — —Red.

Asymmetry of Fields in Homonymous Hemianopsia.—Henschen,[1] Roenne,[2] A. Meyer,[3] Schirmer,[4] Wilbrand and Saenger,[5] Cushing,[6] Traquair,[7] and others have called attention to what many of us have observed in perimetric work, namely asymmetry of fields in homonymous hemianopsia.

Cushing was the last to lay stress upon this clinical entity and his cases reported were later discussed by Traquair. In Cushing's cases of tumors of the temporal

[1] Handbuch der Neurologie, vol. **1**, pp. 903–904: vol. **3**, p. 773, *et seq.*
[2] Klin. Monatsbl. f. Augenheilk, 1915, **54**, 399.
[3] Tr. Assn. Am. Phys., 1907, **22**, 7.
[4] Arch. Ophthal., 1912, No. 2, **41**, 136.
[5] Die Neurologie des Auges, 1917, **7**, 152, *et seq.*
[6] Tr. Am. Neurol. Soc., 1921.
[7] British Jour. Ophthal., June, 1922, p. 251, *et. seq.*

lobe, the field homolateral to the lesion seemed to be affected more than the contralateral field. In some of Cushing's cases and in others recorded in literature, a hemianopic defect was noted on one side and a quadrantic sector on the other. This particular type of incongruity is easily explained. Remote pressure on the chiasm or even on an optic nerve must necessarily be assumed to explain the phenomenon. It is not a type of pure hemianopsia.

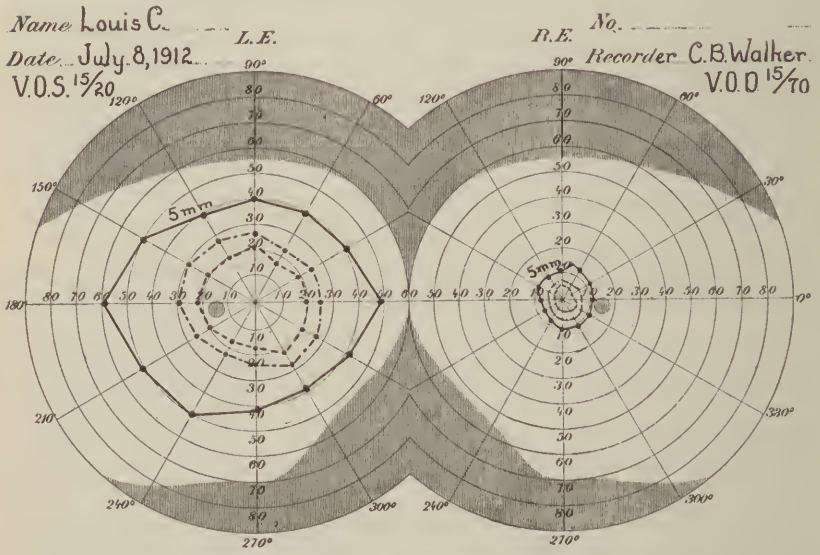


FIG. 142.—Fields taken before operation which disclosed endothelioma of the right temporal lobe. (Cushing.)

A second type, reported by Cushing and others, is half-visual loss in one field and concentric contraction in the other. (Fig. 142.) If the concentric contraction is limited to the preserved part of the field, the presence of a papillitis or choked disc and subsequent consecutive atrophy will explain it. If concentric contraction is complete and surrounds the point of fixation on all sides, the homonymous defect is not of tract origin but further forward, and the concentric field may be explained by postneuritic atrophy or by hysteria.

The types of incongruity which are more perplexing

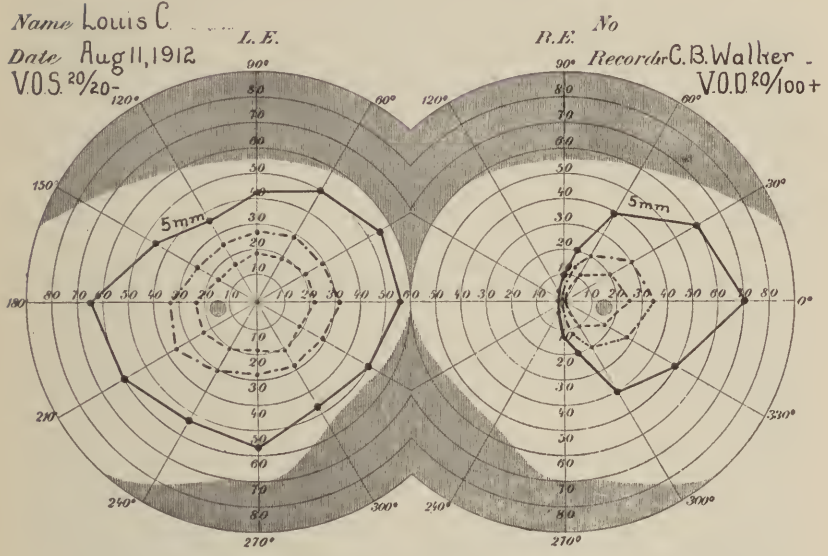


FIG. 143.—Fields one month after those shown in Fig. 142. Tumor as yet not removed. Note beginning upper temporal defect on the left with complete right hemianopsia. (Cushing.)

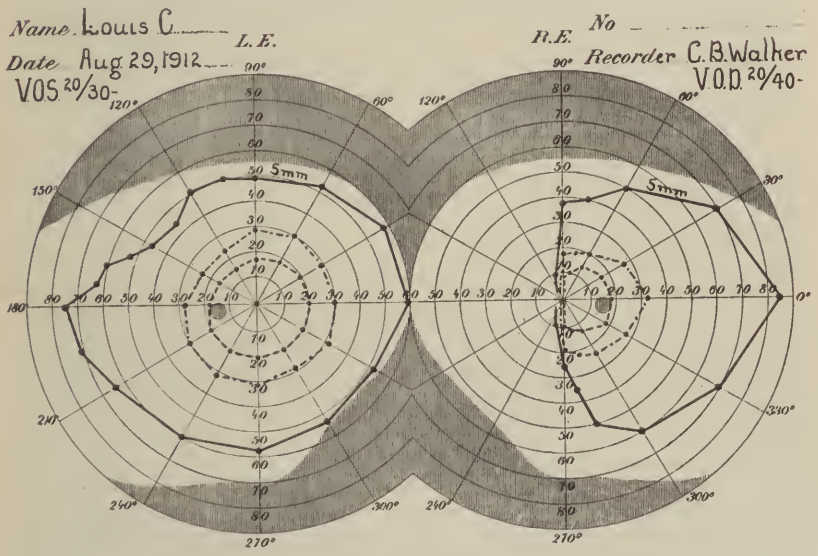


FIG. 144.—Three days after tumor extirpation. Note widening of the fields compared with Fig. 143. (Cushing.)

are those in which the asymmetry is not so marked and yet the fields are sufficiently unlike as to cause comment. This group of incongruities may be attributed to the following causes: (1) Poor technic; (2) to the dissociation of the nerve fibers of corresponding retinal points, from chiasm to cortical centers; (3) to the difference in the relative retinal sensitivity of corresponding retinal points and of the various parts of the retina. Of these causes, the first and the last are the most important and are responsible for the greater number of incongruities, while the second, although of much anatomical interest, plays a minor role.

Errors in technic are due to lack of care on the part of patient and physician, to faulty fixation, tilting of the head, poor illumination, improper preëxposure and surrounding field for colored stimuli, and, finally to stimuli which are too large for accurate work or too small for the testing of peripheral limits, which have been rendered even more insensitive by diseased processes. All these errors are easily recognized and correctable.

The second factor ascribed as a cause for incongruities is an anatomical one. Nerve fibers from corresponding retinal points approximate each other in the chiasm. The uncrossed fiber is brought into functional relationship with its crossed mate in the posterior part of the chiasm. We have no definite knowledge of the exact proximity of the two correlated fibers until they reach the cortical centers where they must necessarily be united to create a single impression. They may or may not be in contact in the tract. Otto Schirmer[1] believes that Bernheimer has proved that the crossed optic fibers occupy mainly the lower part of the chiasm, while the non-crossed fibers are limited to the upper half and form a closed bundle. Shortly after reaching the tract the fibers mingle. At all events, no marked asymmetry can develop from

[1] A Case of Homonymous Hemianopsia, Arch. of Ophth., 1912, **41**, 139.

lesions of the tract, although slight differences might be observed.

In the optic radiation, Adolf Meyer was able to recognize three distinct tracts or segments which make up the geniculo-calcarine visual pathway; a dorsal, lateral and ventral segment. The dorsal and lateral follow a direct path around the posterior horn of the lateral ventricle to their destination in the calcarine cortex. The ventral bundle, according to Meyer, makes a long arched detour forward and downward around the temporal horn of the ventricle in the temporal lobe, then proceeds backward to its destination in the calcarine fissure. Whether associated fibers travel back by the same or by different paths has not been clearly demonstrated. The only evidence thus far produced which tends to show that these functionally associated fibers, destined to carry impulses which are received as one, may reach the visual cortex along different paths, is asymmetry of homonymous fields. If all other factors which might lead to asymmetry could be ruled out, one would be forced to the conclusion that these associated fibers are not in contact. From studies of fields carefully taken, the author is unconvinced that homonymous fibers are dissociated in their path to the cortex. While it is not possible to determine at what point union of these fibers takes place, it is reasonable to assume that shortly after passing into the tract, they are sufficiently close to functionate as one or at least to suffer disturbance of function together. Positive proof of this close association is wanting, but in the third cause for asymmetry, the evidence is so strong as to relieve one of the necessity of proving that homonymous fibers are in intimate contact.

Ferree and Rand[1] in a series of studies in retinal sensitivity demonstrated in a scientific manner a fact which is well known clinically, namely that the nasal

[1] Some Contributions to the Science and Practice of Ophthalmology, International Congress of Ophthalmology, Washington, D. C., 1922.

and superior retina is more responsive to stimuli than are points on the same meridian located in the temporal and inferior parts of the retina. In Cushing's cases

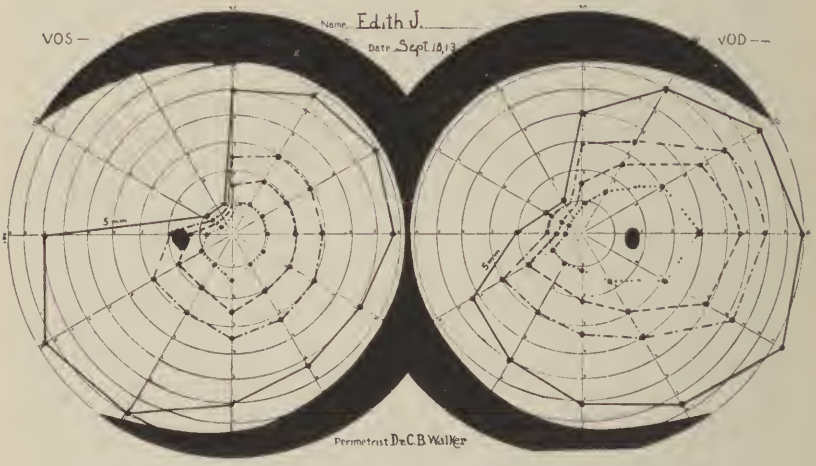


FIG. 145.—Gliomatous cyst in right temporal lobe. (Cushing.)

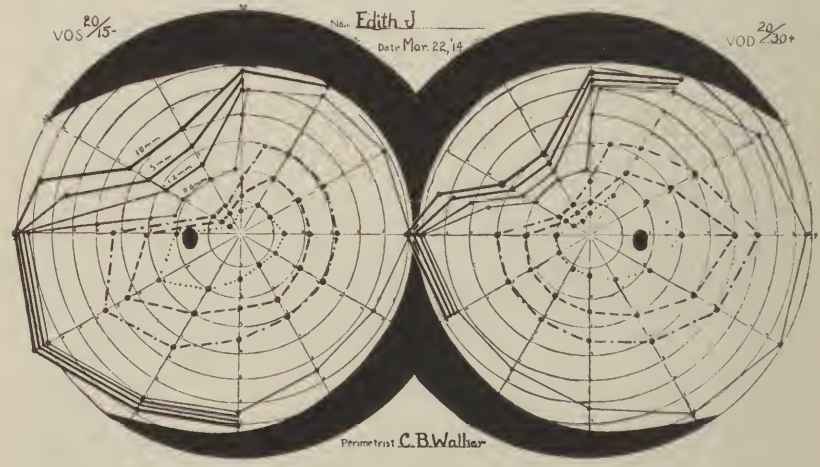


FIG. 146.—Fields sixteen days after operation disclosing gliomatous cyst in right temporal lobe. (Cushing.)

of temporal lobe lesions the defects in asymmetric fields of pure homonymous type showed greater advance on the side homolateral to the lesion. This is exactly as one would expect to find them if due to

varying degrees of retinal sensitivity. The homolateral field represents the temporal retina and the contralateral field, the nasal retina. A careful analysis of each field of this character recorded can be explained on this basis. In fact, one can go a step further. In the extreme periphery of the temporal field, there is a broad band which is not covered by functionating corresponding retinal points in the nasal field. (See Binocular Fields, page 48.) This part of the field may be lost without evidence of disturbance of the opposite corresponding field.

A third factor should be considered as having a bearing upon the cause of asymmetry. If the invasion of the homolateral field is uniformally greatest, as Cushing and others have pointed out, asymmetry cannot logically be ascribed to a lack of propinquity of associated nerve fibers, because to do so would imply that each lesion must always develop in the same general direction. An asymmetry from such a source is irregular and different in every case. On the contrary, the difference in nasal and temporal retinal sensitivity is relatively the same in all individuals, *i. e.*, the nasal retina is more sensitive than the temporal retina.

Disease of the Cortical Visual Centers.—The optic radiation of Gratiolet is distributed to the visual centers in the calcarine cortex above and below the calcarine fissure. As already pointed out in the chapters on Anatomy, the macular center is in the posterior tip of the hemisphere. The centers along the upper lip of the fissure represent the superior retina and those along the inferior lip, the inferior retina.

A field typical of a lesion in this area, like in tract and radiation disease, is homonymous hemianopsia with as a rule *sparing of the macula*. In tumor formation, the hemianopsia may at first be partial; in vascular occlusion of the lower part of the calcarine area, as shown by loss of the upper quadrants, and later the upper area, the hemianopsia is well defined and complete. Bilateral lesions give rise to varied types. In Fig. 150 are the fields of Weymann's case

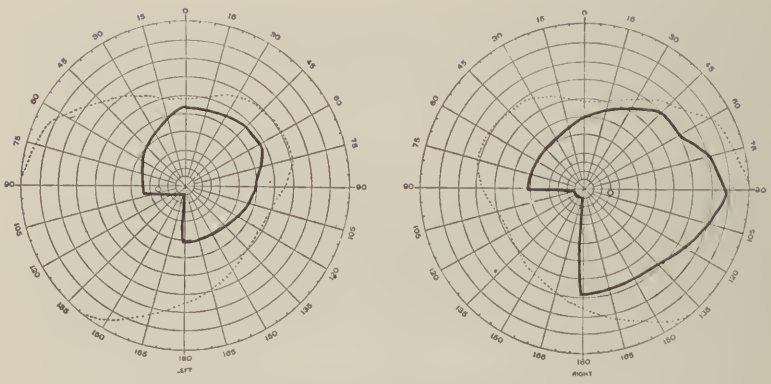


FIG. 147.—Hun's case of quadrant anopsia.

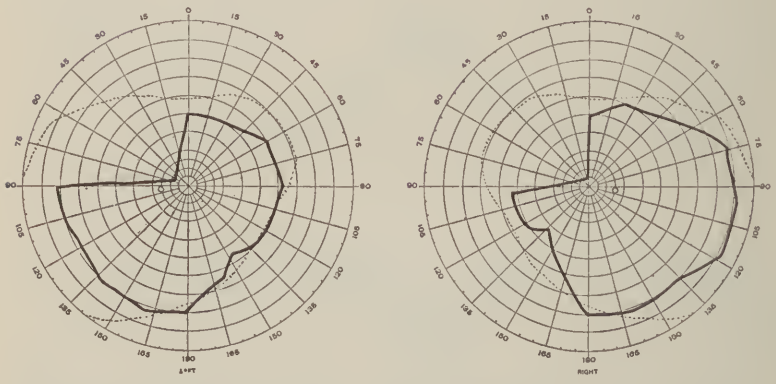


FIG. 148.—Left superior quadrant anopsia. Case of Beevor and Collier.

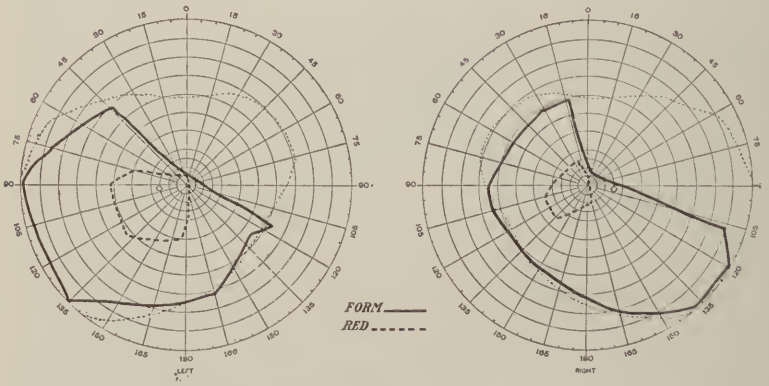


FIG. 149.—Incomplete hemianopsia. (Posey.)

reported in *Am. Jour. of Ophthal.*, 1894. The case was one of lues in an adult. Right hemiplegia followed sudden unconsciousness and was accompanied by a left superior quadrant anopsia and right inferior quadrant anopsia, both homonymous in character.

Fig. 141 represents the fields of a similar case which occurred in a young girl, aged sixteen years. The patient had severe headaches, with a bilateral choked disc of 7 D in each eye. Fields taken before operation were markedly contracted, with an irregular superior binasal defect. After an occipital decompression, the choked discs subsided, leaving partial residual atrophy and field defects as shown in Fig. 141. The Wassermann was positive.

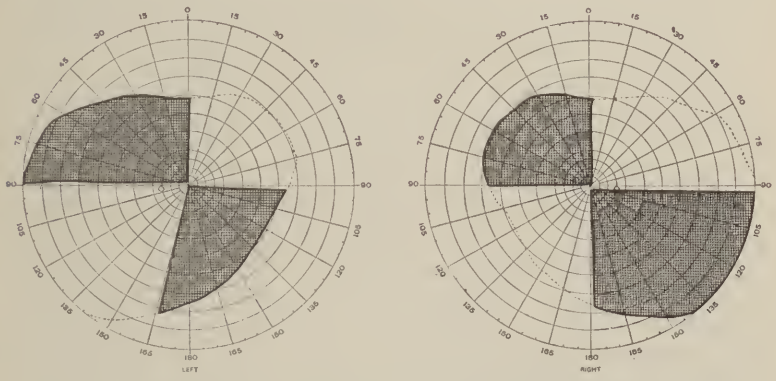


Fig. 150.—Left superior quadrant anopsia and right inferior quadrant anopsia. Weymann's case. Lesion in each cuneus.

Posey's interesting case of Permanent Quadrant and Hemianopic Loss following so-called "Migrainous Attacks," Fig. 160, occurred in a woman, aged forty-six years. She awoke with a headache and blurred vision which she attributed to a bilious attack. The field defects, as shown in Fig. 160, remained permanently. Posey attributed the condition to a hemorrhage or thrombosis following prolonged spasm of an artery in the region of the cuneus. Without associated symptoms, it is difficult to differentiate homonymous hemianopsia of cortical origin from that of the radiation.

Sparing of the maculæ is a phenomenon which is

characteristic of lesions posterior to the primary optic centers. In cortical disease, however, it is especially well emphasized. Studies of war injuries by Holmes, Lister, and others have located the macular cortical areas in the posterior tip of the hemispheres along the calcarine fissure. Morax distinguishes two distinct zones—the foveal zone which is very narrow, extending one, to one and a half degrees around the point of fixation, and a macular zone which extends from five to ten degrees around the fixation point. The line of separation may pass close to the fixation point in complete hemianopic involvement, or the entire macular

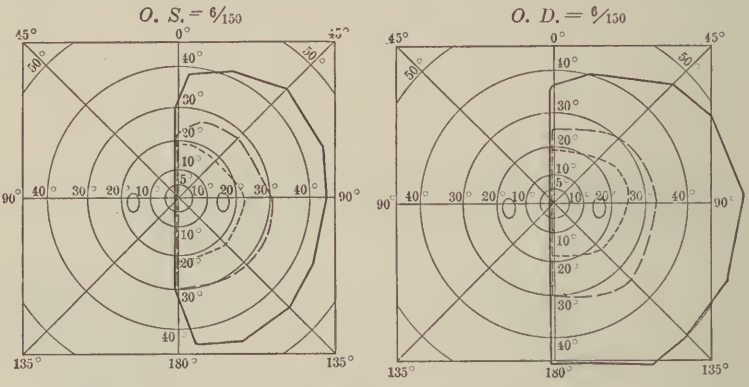


FIG. 151.—Homonymous hemianopsia in an old lady aged seventy-three years, due to a fall. (Hemorrhagic.) No motor symptoms. Patient able to read with corrected glasses. 5° Test object. ————Form; — — — blue; — — — — —Red.

zone may escape. In the latter instance, the line of separation will pass around the macula five or ten degrees from the fixation point. The latter is the usual phenomenon in radiation and cortical diseases although the former also occurs. (See Fig. 151.) Mills[1] speaks of macular cortical representation as follows: "Half-macular representation is not so strictly defined by the vertical dividing line as in the peripheral retinal separation," but "the macular center of one side is more or less representative of the macular fields of both sides." This is confirmed, therefore, by the work of Morax.

[1] Posey and Spiller, The Eye and Nervous System.

PART VI.

FIELDS IN FUNCTIONAL NERVOUS DISEASES.

Clinically, it is at times a difficult matter to classify cases of functional nervous disease, because of dovetailing and overlapping of symptoms. A careful analysis, however, will usually enable the clinician to group his cases in one of three divisions—hysteria, neurasthenia and the traumatic neuroses. In most instances a combination of symptoms will be found, and by a careful weighing of the evidence the case can be properly classified by a preponderance of symptoms.

This classification can, moreover, be further simplified by including the traumatic neuroses either under the head of hysteria or neurasthenia. A final analysis of these neuroses will clearly show that the symptom-complex of a given case is for the most part hysteria, and less frequently neurasthenia. Traumatic hysteria differs very little from hysteria of the usual etiology, and the same is true of traumatic neurasthenia. It is unwise, therefore, to create a third group of functional nervous diseases because of the peculiar etiology. Insofar as the eye phenomena are concerned, and especially the perimetric findings, the author knows of no symptoms which these cases do not share with those who suffer from true hysteria and true neurasthenia. In fact, they are essentially the victims of hysteria with neurasthenic symptoms added. We will therfore discuss the fields in functional nervous disease under Hysteria and Neurasthenia.

A discussion of the general symptoms of these two diseases may be thought not to be germane to the subject of perimetry. A mere statement of perimetric

facts, however, without a clear conception of the conditions which have given rise to the symptoms will be of little value in placing the proper interpretation upon them. In fact, a clear conception of the relation of cause and effect in these phenomena will reduce the perimetric digressions from the normal to a small group of distinctive types with slight variations.

HYSTERIA.—Clinically, it is comparatively easy to differentiate between pure types of hysteria and neurasthenia, and only the borderline cases become confusing. What is the essential element which is active in producing the hysteric phenomena? However numerous the manifestations of hysteria may be, and of whatever character, the underlying principle is that of inhibition, and a careful analysis of each symptom will demonstrate this fact. The means by which each patient arrives at the stage when the disease may be called hysteria will differ widely in each individual, but the ultimate product of analysis will be the condition of inhibition—a condition in which the patient is so influenced by environment, in its broadest sense, that the personal will-power has been lost, or is so feebly active as to be unable to respond normally to normal stimuli. A second factor is added to the enfeebled will-power, namely, either failure of the normal sensory end-organs to receive impressions, or failure of the end-organs to produce the normal result of their stimulation upon the consciousness of the patient. It is alleged by Binet and Janet, as quoted by de Schweinitz, that patients suffering from hysterical amaurosis, when placed under hypnotic influence, can recall what they saw before the hypnotic state was induced, during the amaurotic period. This would tend to argue for the integrity of the sensory end-organs. It is unnecessary at this time to analyze the general symptoms of hysteria to illustrate this conception of the disease. Every physician will be able to recall from his practical experience instances to which he can apply this principle. It is but pertinent to add that the therapeutic measures

which have effected cures, or have relieved these patients, have been in the line of suggestive therapeutics.

It is interesting to draw a brief analogy between the general symptoms and the eye symptoms of hysteria. Anesthesia of the skin finds its analogue in the eye in hysteric amblyopia and amaurosis. Not only is this condition bilateral, but in hemianesthesia of the body the amblyopia or amaurosis may be unilateral. Local areas of skin anesthesia may be represented in the retina in the form of scotomata. Muscular palsy, so frequently observed as hemiplegia, monoplegia, etc., occurs in the eye in external or internal, complete or partial, ophthalmoplegia. Paralysis of the sphincter muscles of the bladder, or tonic spasm of the sphincters, also finds its analogue in the eye in ptosis, tonic blepharospasm, etc. Painful points, or hyperesthesia, of the skin, are similarly represented in the eye in photophobia, lacrimation, etc.

The retina is a sensory end-organ which is especially well adapted to illustrate the vagaries of the symptom-complex of hysteria, and the symptoms found are as varied as the complexity of the visual act would lead one to expect. Three types of changes, however, are especially characteristic: (1) Concentric contraction of fields, with or without central amblyopia; (2) tubular fields; (3) reversal of color fields.

Amaurosis need not be considered here, because when the eye is blind to all forms of stimulation the form and color fields cannot be elicited. It is well to emphasize the fact that no part of the retina enjoys immunity in hysteria, and that any variation of the field observed in organic disease of the visual tract may be found in hysteric disease. This latter observation is not generally accepted, but the author's personal experience has been that the possibilities of field changes in hysteria are only limited, with a few exceptions, by the patient's knowledge. It would be rare indeed to find a condition of homonymous hemiamblyopia limited to central vision, as it is exceptionally

rare in organic disease. Homonymous hemianopsia has been observed, and other irregularities have been developed on the perimeter which follow very closely similar phenomena observed in organic disease. From these facts just set forth, one might be led to believe that hysteric perimetric phenomena after all are only a simulated condition and the result of wilful deception on the part of the patient. They are not the result of malingering or wilful deception but are the result purely of inhibition. The amaurosis of hysteria, for instance, may be relieved at times by the placing of a plain lens before the amaurotic eye, with the suggestion of possible relief of the blindness, especially when this is done in an authoritative and convincing manner. No amount of suggestive therapeutics would cause the malingerer to see, and nothing short of absolute detection of the fraud by a trick would bring back the sight of one who wilfully deceives.

Concentric Contraction. — Most characteristic and probably most frequently observed, is the circular shape of the field contracted to various degrees. Contraction almost to the center will often be found. What is usually observed is a form and color field of almost equal size. In other instances, color fields may be contracted in their usual order and in proportion to the reduction of the fields as observed in optic neuritis. The rule, however, is atypical of organic disease, although resembling it. Large reëntering angles are rarely found. Given a normal eye-ground with form and color fields contracted and of approximately equal size, the diagnosis is presumably hysteria. This contraction may be associated with a central scotoma, or even an annular scotoma, instances of which have been reported in literature.

Tubular Fields.—If a doubt exists as to the genuineness of the hysterically contracted field, further proof will be found in varying the distance between the patient and the blackboard or campimeter. Parenthetically it may be added that the campimeter is an

ideal instrument with which to measure this type of field. Under normal conditions the field will enlarge as the patient recedes from the blackboard. (See Fig. 52.) In hysteria, however, the same size of field may be obtained at any distance, as shown in Fig. 152, a symptom which tends to confirm the hysteric character of the first type of field mentioned. This type is known as the tubular field. It occurs only in hysteria and in malingering.

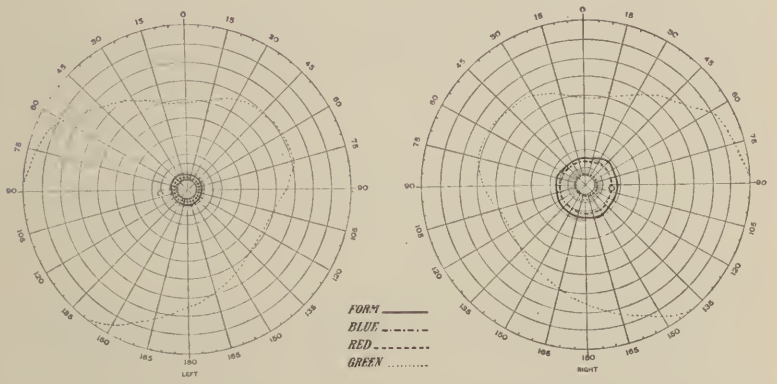


FIG. 152.—Hysterical fields. Patient, aged sixteen years. Concentric contraction. Tubular fields and reversal of color fields.

Reversal of Color Fields.—The third type of field which, in itself when carefully taken and analyzed, and in conjunction with one or both of the other forms mentioned, is characteristic of hysteria, is the field in which the order of colors is reversed. In this field the red may be smaller than the green, or as de Schweinitz believes, the red may be enlarged to reach beyond the blue—a condition possibly of hypersensitiveness to red. In all probability it is due as much to insensitiveness of the retina to the blue elements. Hyperesthesia of the skin is not unusual, and hyperesthesia of the retina to one or more of the colors is entirely within the range of possibility. However, the eye phenomena, for the most part, are manifestations of lowered sensibility, rather than hypersensibility.

Furthermore, it is well to remember that in early chorio-retinitis with questionable eye-ground change, contraction or defect of the blue field may be an early perimetric finding. In hysteric reversals, also, form fields may be approximately normal. When, therefore, the red-blue fields are reversed, and the first and second types of hysteric fields are absent, the evidence should be carefully weighed before classifying the field as functional. Instead of simple reversals of the colors, interlacing may be found. If such a field is obtained, it should be immediately retaken with special care as to the position of the patient's head. A slight shifting to one side may be responsible for this form of defect. It may, however, be a genuine hysteric manifestation. These are the types, therefore, which are especially characteristic of hysteria. Each one of the three may be present in the same patient, and if present would be strong evidence of the hysteric character of the disease.

Dyschromatopsia, Color Amblyopia.—Dyschromatopsia, color amblyopia, and other forms of disturbance of the field may be found. They, however, are but variations of the types spoken of, and in themselves are not diagnostic.

The literature on the ocular evidences of hysteria, and especially perimetric changes, is voluminous, and almost every phase of change observed in organic disease has been reported in hysteria. Many of these symptoms are not distinctive. They should, however, receive due consideration, and because of their rarity be weighed in the balance all the more carefully.

By some investigators the oscillating field is included in the hysterical phenomena. It is, however, a phenomenon more strictly neurasthenic, and will be discussed under Neurasthenia.

Neurasthenia.—The essential element in neurasthenia is fatigue—mental and physical. The inability of the patient to concentrate and sustain thought, muscular asthenia, and its secondary irritability, are

a group of phenomena which make up the symptom-complex of neurasthenia. Unlike hysteria, this condition is usually the result of a long-drawn-out enervating process—a product of overwork or of the tension of certain forms of occupations and professions. The strong, therefore, because of their overestimated power of endurance, are as often the victims of neurasthenia as those who have less stable nervous systems.

The perimetric symptoms are no exception to the rule in this disease. They are similar in character to the general symptoms. Fatigue of the retina, probably of a nutritional character, and inability to concentrate in conscious mental acts, are the forces which bring about the perimetric changes. It so happens that many cases of pure neurasthenia become mixed in time with hysteria, and therefore the perimetric findings may be composite. This fact will account for the rather complicated perimetric phenomena described in text-books and literature as of neurasthenic origin. If one should add to the manifold evidences of hysteria the elements of mental and physical tire, no end of composite phenomena would be the result. Essentially, in making a differentiation between hysteria and neurasthenia, in the field changes, the author is in accord with von Reuss, who contends that constant visual field changes are hysteric and variable field changes are of the neurasthenic origin. This expresses the dominating characteristics of the fields which harmonize best with our conception of hysteria and neurasthenia.

It is doubtful whether fatigue alone of the retinal elements, due to faulty nutrition, or fatigue alone of the concept centers, will explain all of the field phenomena in neurasthenia. Evidence of retinal fatigue, as shown in the spiral field, does not account for the occasional lowering of central vision, which can only be explained by fatigue of the higher visual centers.

Fields as Result of Fatigue.—In profound neurasthenia if the form field, for example, is taken, beginning at

the temporal side and continued indefinitely, a form field will be defined as illustrated in Fig. 53, known as the spiral field of von Reuss. This illustrates most graphically the element of fatigue. Unlike hysteria, it begins in the periphery, where the retinal elements should first show evidence of nutritional change, and gradually approaches the center.

Wilbrand's exhaustion type of visual field is really an expression of the same phenomenon. He arrives at his conclusions in a slightly different manner. Beginning on the temporal side, the test object is slowly moved across the horizontal meridian and the

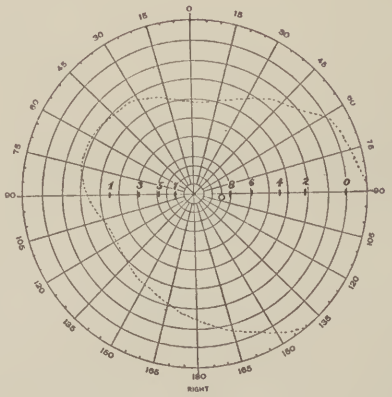


FIG. 153.—Wilbrand's exhaustion type of field.

points of entrance and exit of the test object are noted. The object is now passed slowly back and across the same meridian and the points of entrance and exit again noted. By continuing this process, as in Fig. 153, these points approach nearer and nearer to the center. The test may be applied to any meridian. It is not a special form of field but a convenient method of demonstrating retinal fatigue, if present.

Another method of eliciting the evidence of fatigue is by Förster's method, which is illustrated in Fig. 154. The test object is passed from the temporal side to the nasal side, the point of entrance and exit being noted.

The same measurements are made along another meridian always from the temporal to the nasal side, until the field has been taken. If the process is now reversed, and the test object is passed from the nasal to the temporal side, the field as indicated above will appear. Of the methods mentioned, Wilbrand's is probably the quickest and most satisfactory, although the spiral field shows best in a diagrammatic way the presence of fatigue. Concentric contraction to any marked extent is evidence of a probable hysteric complication. The

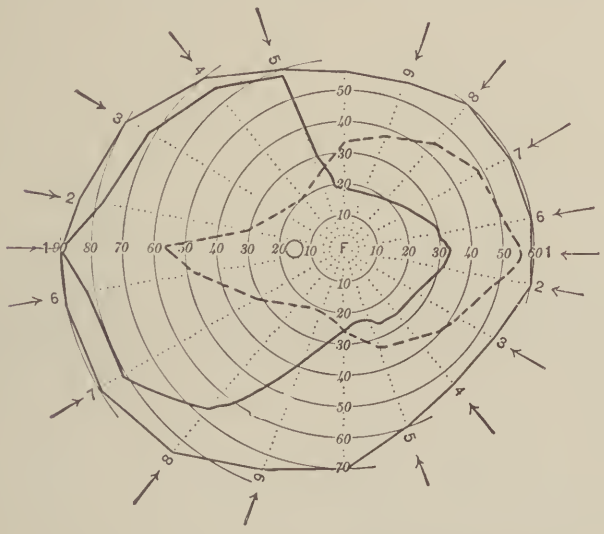


FIG. 154.—Förster's method of taking exhaustion field.

same may be said of marked reduction in central vision, and of the presence of scotomata of any enduring character.

Scheele's theory of a homonymous type of exhaustion field, *i. e.*, exhaustion manifested in corresponding retinal halves, has not been substantiated. It could only be possible if the exhaustion phenomena originated in the cerebral cortex and were limited to one side.

Oscillating Fields.—Wilbrand claims that under certain circumstances, instead of a progressive fatigue

in passing the test object through any meridian, a field similar to that represented in Fig. 155 will appear. In other words, the test object will momentarily disappear, only to reappear again in several points in the same meridian. As neurasthenic patients have difficulty in reading because of the momentary blurring and running together of words and letters, this type of field is within the range of possibility. The author has never been able to elicit a field of this sort in any of the neurasthenic cases which he has examined, although occasionally a patient will speak of momentary dis-

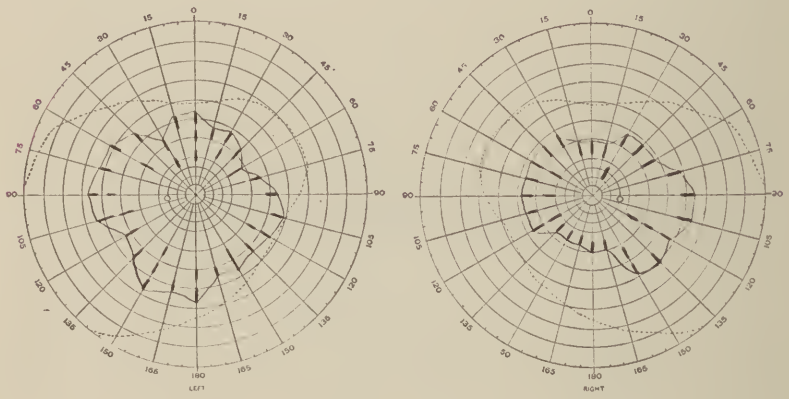


Fig. 155 *a* Fig. 155 *b*

Fig. 155.—Oscillating fields in a case of post-traumatic psychosis studied by Major Edmond B. Spaeth, Walter Reed Hospital, U. S. Army General Hospital.

appearance of the test object. In Fig. 155 are recorded the fields of a patient suffering from post-traumatic psychosis, studied by Major E. B. Spaeth.

The fields which are obtained in neurasthenia are essentially fatigue fields. They are not, therefore, peculiar to neurasthenia, but are found in modified forms in other diseases. It is, however, the element of fatigue which is exemplified in them, and in no condition is this element so marked as in neurasthenia.

Practically nothing has been said of the color fields in neurasthenia. Colors behave similarly to the white

object, and the same phenomena described for form may be elicited with any of the colored stimuli.

Ophthalmic Migraine or Scintillating Scotoma of Migraine.—Migraine is a neurosis which is not unlike epilepsy in its symptomatology and etiology. Heredity, directly or indirectly, is the most important etiological factor. It resembles epilepsy in symptomatology: (1) In the presence of an aura in a considerable number of cases; (2) in its explosive character; (3) in the inhibition which follows the overstimulation of the gray matter; (4) in the irregularity of the recurrences of the attacks.

Entoptic studies made by the patient are of some value in this disease because it usually occurs in an intelligent class of people. Men and women known for their scholarship frequently are the victims, and their entoptic observations are for the most part dependable.

Two types of the ophthalmic variety are recognized: (1) The form accompanied or followed by distinct scotomata; (2) a milder type of disease known ordinarily as "sick headache."

When typical in onset the first variety is ushered in by dazzling or shimmering lights usually situated to the right or left or occasionally covering the greater part of the field. What is even more characteristic is what is known as the fortification spectrum. The dazzling lights assume the form of a crescent or comet and zigzag back and forth in the field for an appreciable time. In some instances the fortification spectra are highly colored. One patient described the peaks as of gold and the bases of rose. In nearly all forms the periphery is clear and the spectra are to the right or left of the center. These periods of overstimulation are soon followed by a period of exhaustion and the shimmering lights give way to dark areas in the field situated either to the right or left of the center—scotomata, homonymous in character. (See Fig. 156.)

Less frequently the attack is ushered in by the

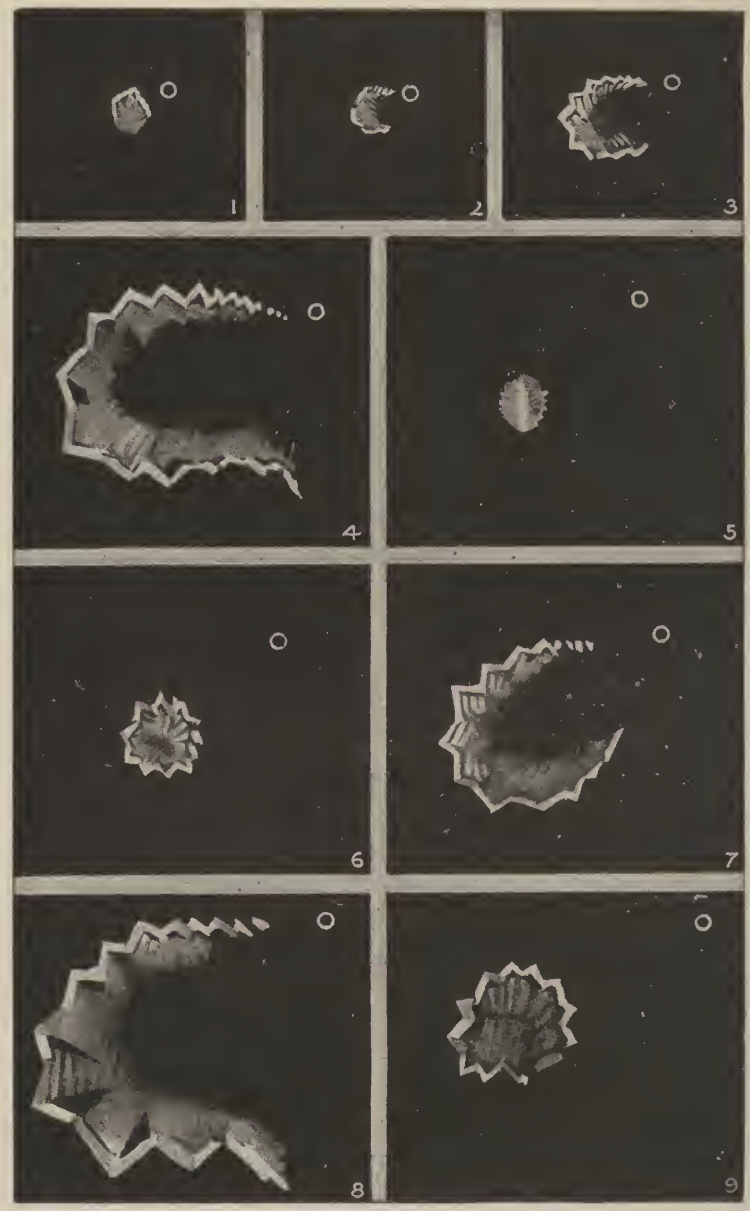


FIG. 156—Nos. 1 to 4 represent the gradual evolution of the fortification spectrum of migraine as seen in the dark commencing quite close to the fixation point. Nos. 5 to 8 represent similar phenomena commencing some distance from the fixation point. No. 9 represents a fresh attack beginning whilst No. 8 was still at its maximum; such secondary attacks never develop fully unless they occur in the other half of the visual field. The small circle in each figure represents the fixation point. The bastioned outline is often brightly colored, and the whole figure has a "boiling and trembling" motion. From Dr. Airey's paper, Phil. Transac., 1870, 247. Reproduced by kind permission from R. Foster Moore's Medical Ophtholmology.

appearance in the field of a dark spot which gradually enlarges, the center clearing as the periphery enlarges. At times the dark spot becomes luminous in the periphery. At other times patients have hallucinations in these areas. Posey reports the case of a woman who saw a bull's eye in the center of the dark area. At times the dark area which follows the scintillations covers the entire half-field of vision, producing right or left homonymous hemianopsia.' In other instances the spectra are replaced by quadrant defects in the field, corresponding retinal quadrants being affected. In any variety the period of overstimulation is brief and the phenomenon of scotomata is accompanied by a hemicrania or a nervous form of sick headache. The hemianopic scotomata are observed by the patient as positively blind areas and perimetric studies will demonstrate their presence if the examination is made before the phenomenon has disappeared. In this form of scotoma the patient may refer the blind area to one eye because it occupies the right or left of the field. It, however, is a bilateral condition, hemianopic in character.

Perhaps a more frequently observed type of scintillating scotoma is that known as a pyrotechnic display of lights. Shimmering lights of all colors will dazzle before the patient's eyes for a moment, and immediately there will follow indistinct dark areas which rapidly disappear. The phenomenon is similar in character to the fortification spectrum, but as a rule it represents a milder type of disease. Headache follows as in the severer form of the disease. The headache is of the hemicranic type.

Perimetric studies of the latter variety rarely show scotomata. A contraction of the form and color fields can usually be demonstrated. In the hemianopic variety, however, if studies are made early the scotomatous areas can be clearly defined and the fields on the unaffected side may show contraction.

In Fig. 157 the fields of a patient who suffered

repeatedly from attacks of migraine with scintillating scotomata are shown. Inequality in the size of the form fields in this case is due to a condition of anisometropia.

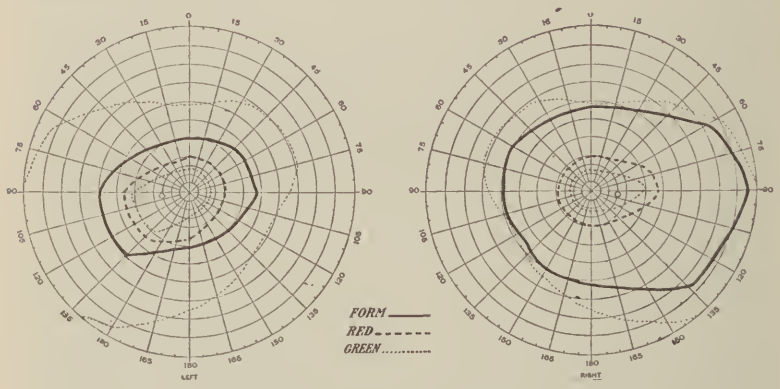


Fig. 157.—Scintillating scotoma of migraine between attacks.

In Fig. 158 are the fields of the same patient taken within a half-hour after the onset of an attack of migraine. Although no scotomata were found in any

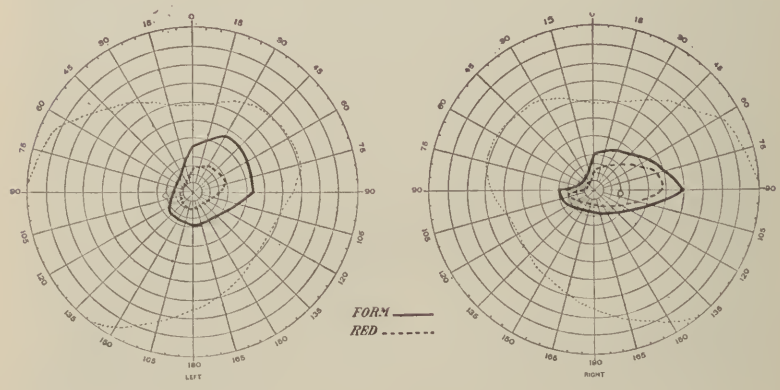


Fig. 158.—Scintillating scotoma of migraine. Same case as in Fig. 157, one-half hour after attack.

part of the field, the hemianopic tendency is well illustrated. Not only are the fields hemianopic, but there is a marked reduction in both form and color fields. The author had the opportunity of studying

this case upon a number of occasions shortly after an attack, and invariably the fields assumed the form shown in the last figure. The hemianopic tendency was so characteristic that the patient described the left homonymous form of hemianopsia typically, the seeing half and the blind half being separated by a sharp dividing line a little to the left of the center.

Dr. William Zentmayer[1] reported an interesting case of ring scotoma in a case of migraine. It is difficult to explain the formation of the complete ring in the right eye, as the irritation or process, whatever it may be which gives rise to the eye phenomena, has its origin

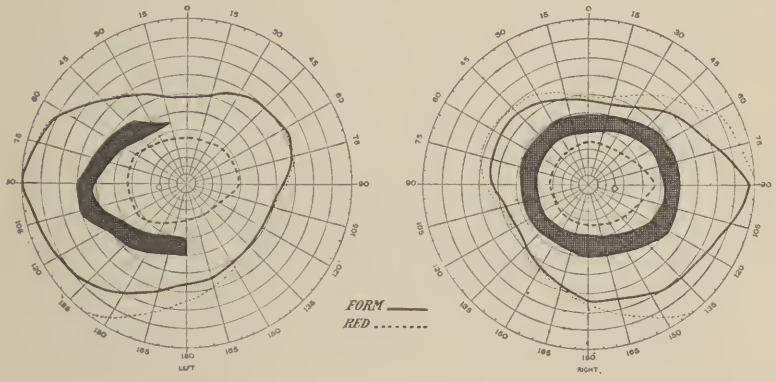


FIG. 159.—Ring scotoma of migraine. (Dr. William Zentmayer.)

in the cuneiform body and therefore should be hemianopic. It is interesting to note, however, that the author reports typical hemianopic defects in the fields after the first few seizures.

Because of the fleeting character of the scintillations one rarely has the opportunity of studying the field immediately after an attack. The entoptic study by the patient, however, is usually dependable, and many of these patients can give graphic descriptions of the color phenomenon, and can make accurate drawings of the scotoma which subsequently appears.

[1] Ann. Ophthal., vol. **21**, 279.

The perimetric phenomena of migraine definitely locate the seat of the ophthalmic variety in the visual cortex and most probably in the calcarine fissure. In a few instances the earliest premonitory sign is a macular scotoma which gradually enlarges but always remains hemianopic. In other instances the upper or lower corresponding quadrants are involved but at all times homonymous. These facts strengthen our belief that the seat of the disease is in the calcarine cortex. The immediate process probably is of circulatory origin, as no constant lesion has been found in patients suffering from this neurosis.

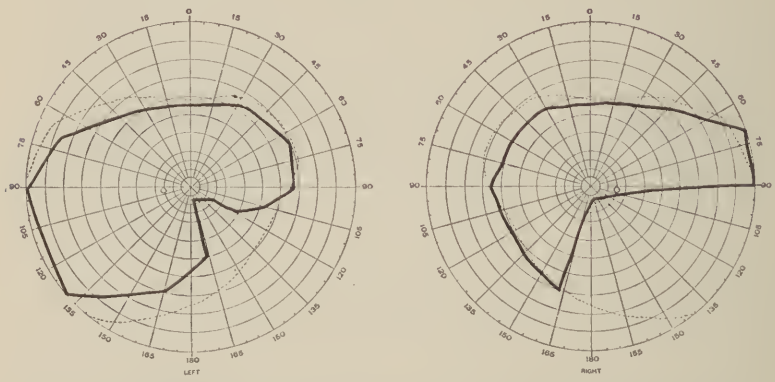


FIG. 160.—Quadrant anopsia of migraine. (Dr. Wm. Campbell Posey.)

A number of cases of quadrant and hemianopic scotomata have persisted for varying periods and some have remained permanently hemianopic. Hoeflmayer, according to Posey, noted permanent hemianopsia in a woman, aged fifty-seven years, for one month after a migrainous attack. Charcot reported a case of permanent hemianopsia following an attack of migraine. Noyes' case had frequent attacks of migraine for ten years. Finally, in a severe attack, left lateral hemianopsia followed, with a contraction of the nasal field of the left eye. At autopsy a clot was found in the right cuneus. Other cases of a similar character have

appeared in literature from time to time. It may be assumed, therefore, that migraine in all probability is due to a spasm of small vessels in the cuneus, and that in those cases in which the fields have remained permanently affected, the oft-repeated attacks of migraine have eventually resulted in permanent occlusion of the vessel with subsequent softening of the brain tissue. The functional disease gives way to an organic lesion.

APPENDIX.

In addition to the use of the perimeter incident to the study of visual fields, the perimeter, or its modifications, may be employed (1) to study the field of monocular fixation; (2) to study the field of strabismus; (3) to measure the angle kappa; (4) to study and chart diplopia, and (5) to locate foreign bodies.

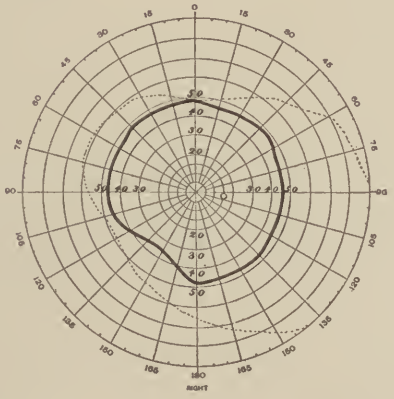


Fig. 161.—Field of monocular fixation of the right eye recorded upon an ordinary perimetric chart.

The Field of Monocular Fixation.—The field of monocular fixation may be measured approximately either on the perimeter or campimeter. The patient is seated before the perimeter or campimeter as in the taking of the visual fields, with one eye covered, the eye under examination fixing upon the center of the instrument. A test object of fine points definitely separated, or as suggested by Duane, fine parallel lines, is slowly moved from the point of fixation on the arm of the perimeter or on the campimeter, and the patient is instructed to follow the test object with the

eye until the parallel lines become blurred or indistinguishable. This point will mark the extreme rotation of the eye in that particular meridian. Eight points of rotation should be measured—out, in, up, down, up and in, down and in, up and out, and down and out. A field of fixation may in this manner be completed, as suggested by Landolt and others, and for this purpose ordinary perimetric charts may be employed.

Fig. 161 illustrates the normal field of the right eye recorded on an ordinary perimetric chart, the measurements being according to Landolt. Duane's measurements on his tangent curtain are:

Outward rotation	51 degrees
Inward rotation	53 "
Upward rotation	43 "
Downward rotation	63 "

These measurements compare favorably with those taken by Stevens and also Reber on the tropometer. Stevens's figures are:

Outward rotation	50 degrees
Inward rotation	55 "
Upward rotation	33 "
Downward rotation	50 "

Measurement of Squint.—The amount of the deviation in squint may be measured with considerable accuracy on the perimeter. The patient is seated before the perimeter in a dark room and is instructed to fix with the non-squinting eye on an object directly in line with the point of fixation and at a distance of six meters. Both eyes are uncovered. A small electric light, such as is found in a luminous ophthalmoscope, is moved along the arm of the perimeter in the horizontal meridian, until a point is reached where the corneal reflex from the light falls directly in the center of the pupil of the squinting eye, as viewed by the surgeon from behind the perimetric arm. The position

of the light on the perimetric arm is carefully noted and the degree of deviation is read from the back of the instrument, as one would read the degree of field limitation in the same meridian. In convergent squint the light is moved toward the side of the fixing eye; in divergent squint it is moved toward the squinting eye. The results thus obtained will compare favorably with other methods of measuring squint.

ESTIMATION OF THE ANGLE KAPPA OF LANDOLT.—Much confusion has arisen in reference to the angles alpha, gamma, and kappa of Landolt. Academically these angles have a distinct and separate significance; from a clinical standpoint, however, the ophthalmic surgeon is interested in the angle which is apparent to the observer's eye and gives the appearance of a pseudo-convergent or pseudo-divergent squint. The angle described by Landolt under the name of kappa has met with general approval. It is the angle formed by the line of vision and the line which passes through the pupillary axis. The perimeter is ideally adapted to the measuring of this angle. The patient is seated before the perimeter with the eye under examination properly centered upon the point of fixation, the other eye being occluded by a bandage. The light of a luminous ophthalmoscope is now placed over the point of fixation and the position of the corneal reflex of the light is carefully noted within the pupillary space by the operator who is directly back of the center of the perimeter. If the corneal reflex is to the inner side of the pupillary margin, the light is moved along the arm of the perimeter, placed horizontally, until the corneal image is observed to be directly in the center of the pupillary space, the operator's eye being moved with the light, while the patient continues to hold macular vision upon the point of fixation. The point on the perimetric arm at which the light throws its reflex upon the center of the pupillary space is carefully noted, and the degree of deviation is read off from the back of the perimeter. If the corneal reflex falls to the inner side

of the pupillary center, the angle kappa is positive; if it falls to the temporal side of the pupillary center, the angle is negative.

Although of rather short radius, the Schweigger hand perimeter is very practical for this purpose. Its short radius, however, is more apt to lead to an appreciable error than when the measurements are taken upon a standard perimeter of longer radius.

Diplopia.—For the purpose of determining and charting diplopia, the campimeter is well adapted. A red glass may be placed over one eye, the patient being seated before the campimeter in the usual manner. An electric lamp is now moved to the right and left, up and down, up and in, down and in, up and out, and down and out. One object being red and the other yellow will enable the patient to determine readily the direction of the diplopia, the direction in which the diplopia is greatest, and the relation of the true to the false image.

Location of Foreign Bodies.—Foreign bodies in the eyeball have been located with sufficient accuracy to guide the operator in their removal by locating the resulting scotomata on a perimeter or blackboard. Dr. Charles A. Oliver many years ago was fortunate enough to locate a foreign body in this manner. More recently two cases of cysticercus have been located so accurately as to allow the operator to remove them with wonderful precision. In *La Clinique Ophthalmologique*, July, 1914, p. 468, Dupuy-Dutemps reported a cysticercus located subretinally. The position of the cysticercus was located by means of the scotometer. Extraction was done under cocaine by a meridional scleral incision. J. Hirschberg,[1] Berlin, also reported the extraction of a cysticercus from the vitreous which was located by the defect in the visual field. The special advantage of this means of locating foreign bodies lies in the fact that in selected cases the perimeter may enable the surgeon to locate a foreign body, non-metallic and unsuitable for roentgen-ray localization.

[1] Centralbl. f. Prakt., July and August, 1914, p. 192.

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An effort has been made to limit the included titles for the most part to monographs and papers which are the result of individual or collective study of large numbers of cases. Many valuable papers have necessarily been omitted because they either cover the same ground as those which are included in the list, or present reports of cases of typical perimetric phenomena.

The reader will note that many monographs and papers are accompanied by a bibliography, and such articles are marked by a double star. As reference is made in each bibliography to all the important papers bearing on the subject for many years past, the author has confined his bibliography largely to the last decade, during which time the practice of perimetry has made great progress and the contributions have been many and of great value.

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